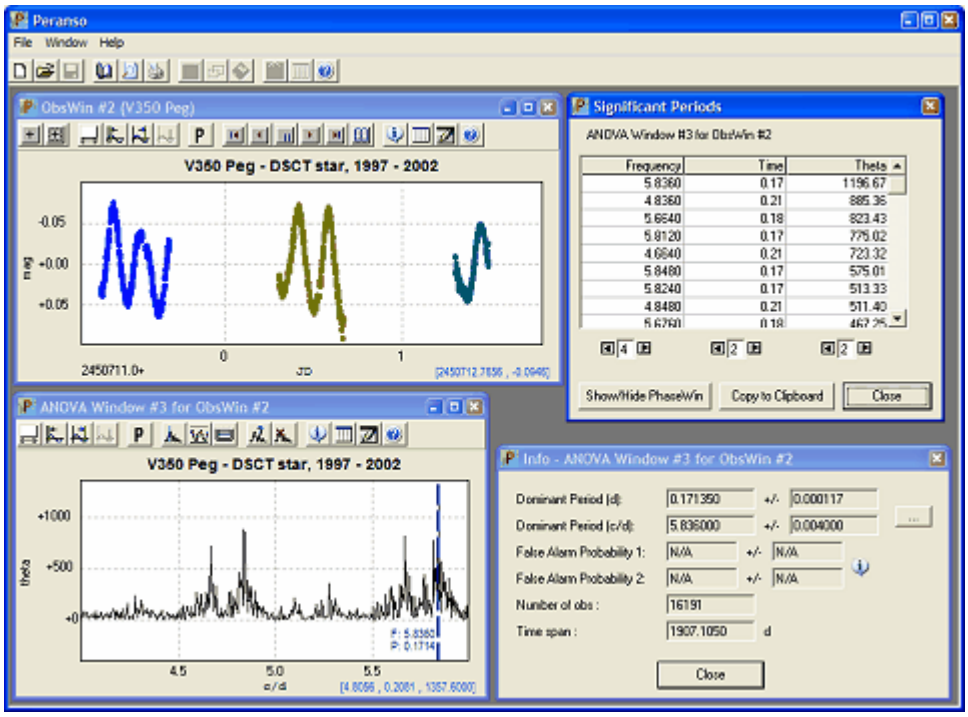
PERANSO®

Light Curve and Period Analysis Software


Peranso
File Window Help
ObsWin #2 (V350 Peg)
V350 Peg - DSCT star, 1997 - 2002
Significant Periods
ANOVA Window #3 for ObsWin #2
Frequency Time Theta
5.8360 0.17 1196.67
4.8360 0.21 885.36
5.6640 0.18 823.43
5.8120 0.17 775.02
4.6840 0.21 723.32
5.8480 0.17 575.01
5.8240 0.17 513.33
4.8480 0.21 511.40
Show/Hide PhaseWin
Copy to Clipboard
Close
ANOVA Window #3 for ObsWin #2
V350 Peg - DSCT star, 1997 - 2002
Info - ANOVA Window #3 for ObsWin #2
Dominant Period (d): 0.171350 +/- 0.000117
Dominant Period (c/d): 5.836000 +/- 0.004000
False Alarm Probability 1: N/A +/- N/A
False Alarm Probability 2: N/A +/- N/A
Number of obs : 16191
Time span : 1907.1050 d
Close

PERANSO 2.0

User Manual

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Peranso

Light Curve and Period Analysis Software

Version 2.0

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Peranso 2.0 User Manual

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Acknowledgments

I have used Peranso for light curve and period analysis during the program's whole development cycle. I have processed hundreds of light curves, tested routines over and over, studied dozens of papers. But I could not have done it alone. I wish to acknowledge the generous help of many friends.

Special thanks go to Dieter Husar for his efforts in testing and providing feedback, and for his perpetual readiness to try out new routines. I'm grateful also to Patrick Wils, Grant Foster, Alan Harris, Nick Lomb, Brandon Tingley who provided valuable support for the implementation of their period analysis methods. I want to acknowledge also the help of Paul Van Cauteren, Patricia Lampens, Sigfried Vanaverbeke, Richard Miles, Sebastian Otero and Aaron Price.

Finally, special thanks to the many users of Peranso, for their positive comments and encouragements.

Tonny Vanmunster, January 2006

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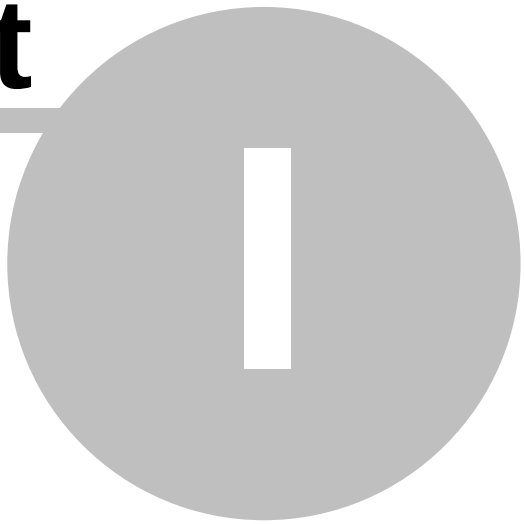
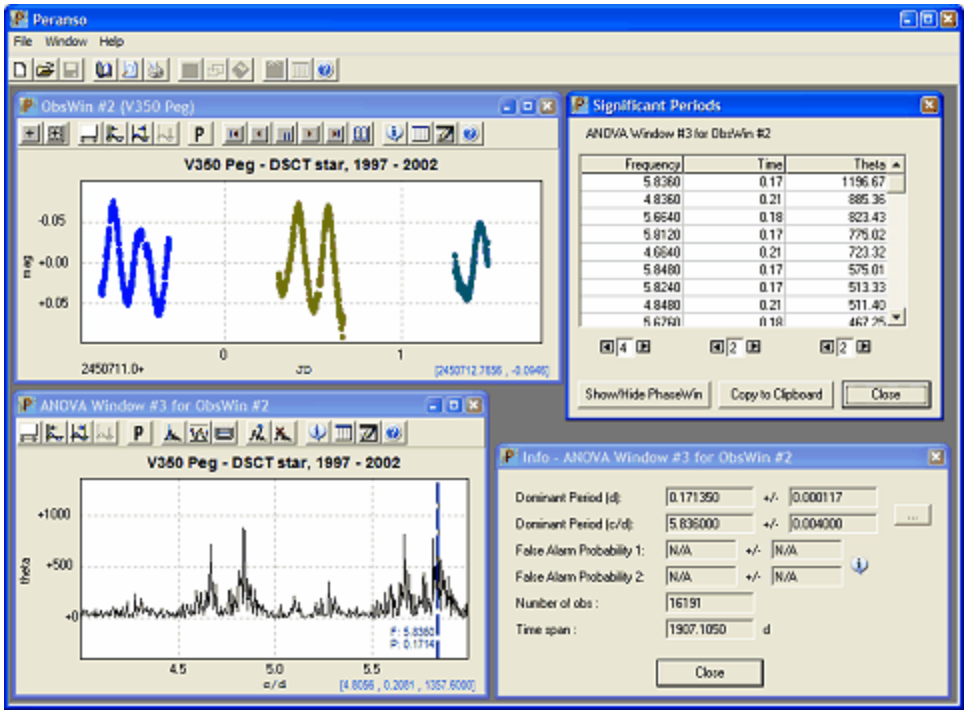


1 Welcome to Peranso 2.0

Peranso offers a complete set of powerful light curve and period analysis functions to work with large, multi-night astronomical data sets, collected by a variety of observers. It is equally performant for the individual observer, who is interested in analyzing his observations of one or more nights.

Substantial attention has been given to ease-of-use and data accuracy, making *Peranso* the most productive period (or time series) analysis software on the market. *Peranso* lets you take control of your data analysis. Forget intimidating manuals and complex commands - powerful light curve and period analysis capabilities are now within your reach.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False Alarm Probability 1: N/A +/- N/A
False Alarm Probability 2: N/A +/- N/A
Number of obs : 16191
Time span : 1907.1050 d
Close

Peranso includes these powerful features :

- An extensive set of period analysis methods to detect periodicities in time-series data : Lomb-Scargle, Bloomfield, Discrete Fourier Transform DFT (Deeming), Date Compensated Discrete Fourier Transform DCDFT (Ferraz-Mello), CLEANest (Foster), Jurkewich, PDM (Phase Dispersion Minimization), Dworetsky, Renson, Analysis of Variance ANOVA (Schwarzenberg-Czerny), Lafler-Kinman, EEBLS (Kovacs) for exoplanet transits, FALC.

- Multiple windows to display observation sets, period diagrams, phase diagrams, etc. Each

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observation set is drawn in a distinctive color, that is consistently used throughout all related windows.

- Powerful data analysis functions for averaging, detrending, heliocentric correction, curve fitting, etc.
- A unique Lightcurve Workbench for advanced light curve analysis, comprising functions for data reduction (binning), polynomial fitting, extremum finding, etc.
- User controlled "prewhitening" routine for elimination of aliases and confirmation of secondary periods.
- Particularly effective multi-periodic analysis function using the CLEANest / SLICK method by Grant Foster.
- Model Function to visualize how selected frequencies/periods fit the observations (CLEANest method).
- Display the Residuals that result from subtracting a Model Function from the observations (CLEANest method).
- Analyse photometric time series in search for periodic transits by exoplanets, using the EEBLS (Edge Enhanced Box-fitting Least Squares) method by Kovacs. Calculate and visualize the EEBLS frequency spectrum, fold the time series over the most significant EEBLS period, calculate the epoch of mid-transit events, the transit depth and duration, graphically display the fit obtained by the EEBLS method.
- Use Tingley's Exoplanet Diagnostic, to calculate how "planet-like" a transit event is, using only the transit period, duration and depth. It is integrated in the EEBLS method.
- Period determination of eclipsing Algol-type (EA) binaries using the EASolver method (Wils). It works on photometric survey data with only few observations showing the variable in faint state.
- Determination of period error values (uncertainties) based on a method by Schwarzenberg-Czerny.
- Sophisticated calculation of False Alarm Probabilities to determine the period significances, using a Fisher Randomization method (Monte-Carlo permutations).
- Extremum finding based on (a) the Kwee-van Woerden algorithm, or (b) local minima/maxima determination through polynomial fitting.
- Handles datasets of >300.000 observations (and probably even much more).
- Temporary deactivate observations and study the impact on your period analysis results.
- Swiftly import observations from Microsoft Excel™, Microsoft Word™, AIP4WIN™, AAVSO, ASAS (All Sky Automated Survey), NSVS (Northern Sky Variability Survey) and other file formats. Full support of the Microsoft Windows clipboard.
- Powerful data and image export capabilities (to file or to clipboard)
- "One-Button-Save" to store all analysis windows on disk and continue your work in identical conditions at a later stage

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- Toolbars, cursors and indicators let you select prominent periods, indicate intervals for refinement of your period analysis, etc.
- Easy navigation bar to step through and zoom in on observation sets
- Fully customizable windows : axes, grids, window annotation, trendlines, colors, etc.

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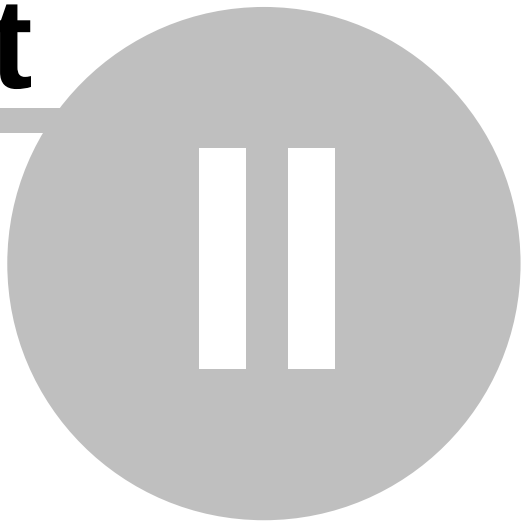
Part



2 Introduction

2.1 Installing Peranso

Peranso uses a common installation script that presents a familiar installation interface to most users of the Microsoft Windows platform. *Peranso* is available in an 'Electronic Distribution' and consists of the program elements and the on-line help.

Installation proceeds as follows :

1. Download the *Peranso* distribution file, named **PeransoSetup.exe**, from http://www.peranso.com.
2. Double click on **PeransoSetup.exe** to launch the *Peranso* installation software.
3. When running the *Peranso* installation software, you need to answer various questions such as which folder to use for Peranso. These questions are self-explanatory. In a normal installation, you should accept the default settings.
4. After the installation has completed, launch *Peranso* by selecting the program from the All Programs folder of your Windows Desktop. The name of the Peranso executable will be "Peranso_XYZ", where "XYZ" refers to the version number of your *Peranso* copy (e.g., 200 refers to version 2.00).
5. As long as you have not registered the software yet, a "**Reminder**" dialog box will appear at start up. Click the OK button to proceed, after which *Peranso* will launch. Trial versions remain operational for 10 minutes.

NOTE

Peranso is shareware. You can use the software - in trial version - for a limited period of time (14 days) for free. The trial version is fully functional, but shuts down 10 minutes after startup (during the 14 days trial period). If you like the trial version, you are invited to register it. This will remove the 10 minutes limitation, and entitles you to receive free updates of the software.

2.2 System Requirements

- Required : PC with 200 MHz CPU, 64 MB memory, 30 MB free hard-disk space, 8-bit display, running Win 98, Win 2000, Win ME, NT or XP.
- Recommended : PC with 500 MHz CPU, 128 MB memory, running Win 2000, NT or XP.

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2.3 Registering your copy of Peranso

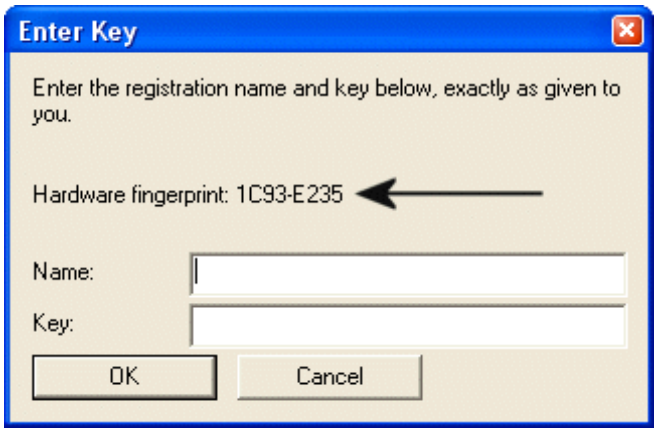
The final installation step of *Peranso* is to register your copy with *CBABelgium.com*. If you have already registered a copy of *Peranso* before on your personal computer, you may skip this section.

Registration of *Peranso* will turn your trial version into a **full version** (removing the 14 days trial period check and the 10 minutes operation limitation). In addition, registered users are entitled to receive free updates of *Peranso*.

As long as *Peranso* is not registered, a "**Reminder**" dialog box appears at start up :

Reminder
This program is not free. It is an evaluation version of copyrighted software. If you use it beyond the evaluation period, you are expected to register it with the author. Please check www.peranso.com for details.
This trial Peranso version closes itself after 5 minutes of operation, without warning.
OK button will be enabled in 6 seconds...
OK
Enter Key
Buy Now!

To register *Peranso*, press the "**Enter Key**" button. A new dialog box "**Enter Key**" appears :



It displays a **Hardware fingerprint** key (indicated with the arrow in the screen shot above) and two input fields, labeled **Name** and **Key**. Write down the Hardware fingerprint key.

To register your copy of *Peranso*, you must send an email to Peranso@cbabelgium.com, containing the **Hardware fingerprint** key. Make sure to exactly copy the Hardware fingerprint key. Any mistake will result in an incorrect registration.

Click **Cancel** to close the dialog box and quit the registration, once you have sent your email with the Hardware fingerprint key.

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A few days later

Shortly after (mostly within 1 – 2 working days), you will receive an email from *CBABelgium.com* with a valid **Name** and **Key**. These are generated on the basis of your Hardware fingerprint key. Please note that the **Name** and **Key** will only be provided if your payment has been received.

Launch *Peranso* again and click **OK** when the "**Key Required**" dialog box (see above) appears. This displays again the "**Enter Key**" dialog box (see above). Then enter the **Name** and **Key** exactly as they are written down in the email you received from *CBABelgium.com*. The **Name** field mostly will be your own name or the name of your company / institute. The **Key** field will be a string consisting of at least 60 characters. Please make sure to exactly copy both fields. Any mistake will result in an invalid registration. Click **OK** when you're done.

If the registration was successful, the "**Key Valid**" dialog box appears. Click **OK** to close this dialog box, after which *Peranso* will launch.

Your copy of *Peranso* is now licensed for use on your personal computer. Evidently, the next time you start *Peranso*, none of the registration steps described in this section, will have to be repeated.

NOTES

1. The **Name** and **Key** that you receive from *CBABelgium.com* are valid only for the specific computer and operating system you are using. It will not allow you to install *Peranso* on any other personal computer.

2. Do not change your personal computer's clock prior to or immediately after installing *Peranso*, as this will make your copy unusable, due to a built-in software protection mechanism.

3. If you purchase a new personal computer, you will have to contact *CBABelgium.com* to request a migration of your *Peranso* copy to this new infrastructure. This is again due to the software protection mechanism used by *Peranso*.

2.4 Software Updates

Software updates for *Peranso* are released from time to time. These updates may be downloaded directly from the *Peranso* Web page, using the URL http://www.peranso.com. Follow the instructions on the Web page.

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If you are a registered *Peranso* user, and want to upgrade your *Peranso* release to a newer version, then simply copy the new *Peranso* file(s) over your existing installation. Read the *Revision history* section of the *Peranso* website for more instructions. You don't have to apply for a new registration key after upgrading (your existing key remains operational), except for new major releases.

Technical Support

CBABelgium.com provides support to registered Peranso users at the addresses listed below.

E-mail	Peranso@cbabelgium.com
World Wide Web	www.peranso.com

2.5 Legal Notes

Limited Warranty

Peranso (hereafter, the *software*) is warranted to perform substantially the tasks described in this document. *CBA Belgium Observatory* (hereafter, *CBABelgium.com*) does not warrant that this *software* is error-free or that it will operate without interruption. The *software* is warranted to perform substantially the operations described herein using the hardware and software explicitly described in this document. *CBABelgium.com* will not be responsible for brand-level peculiarities and changes in computing hardware, operating systems, or computer operating characteristics that take place after the release date of the current version of this *software*. Reasonable efforts shall be made by *CBABelgium.com* to correct software errors reported in writing to *CBABelgium.com*. *CBABelgium.com* does not warrant that all errors will be corrected or that this *software* will meet your requirements. No information, suggestion, or advice, either written or oral, given by *CBABelgium.com* shall extend the scope of the warranty specified here.

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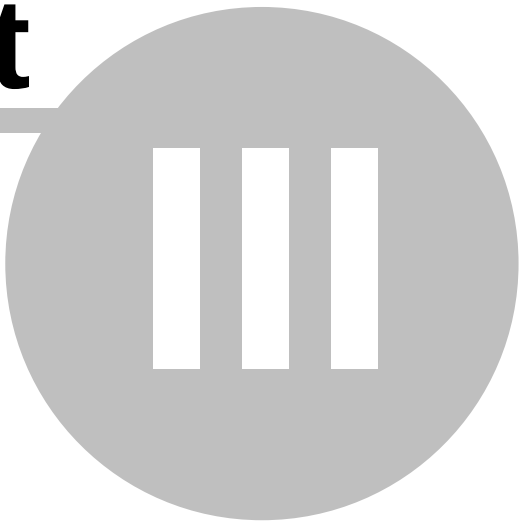
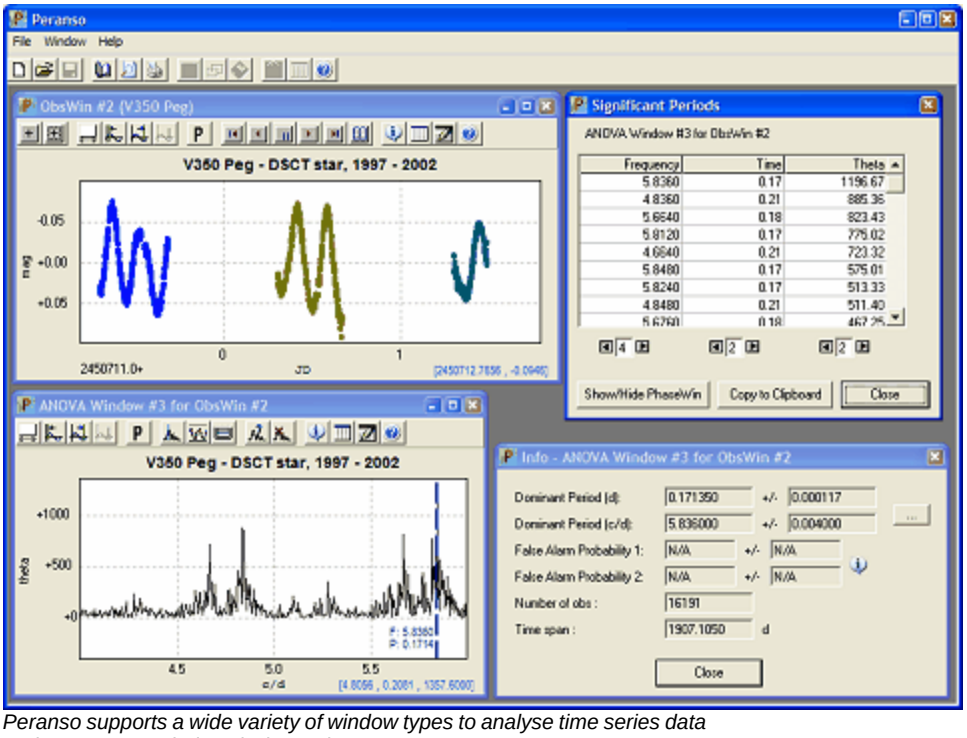


3 The Peranso User Interface

The *Peranso* user interface comprises basic *Peranso* window types and some specific graphical elements such as Cursors, Indicators, etc.. All other *Peranso* graphical user interface elements are common Microsoft Windows entities (dialog boxes, menus, toolbars, etc.).



Peranso supports a wide variety of window types to analyse time series data and to present period analysis results

In the next sections, the three basic *Peranso* window types are discussed in detail :

- The Observations Window (ObsWin)
- The Period Window (PerWin)
- The Phase Window (PhaseWin)

We furthermore explain how to use the mouse and keyboard to zoom in and out on the above windows, and how to activate and deactivate observations. We end this section with a description of Overlays.

3.1 Three basic Peranso window types

3.1.1 The Observations Window (ObsWin)

A *Peranso* Observations Window (short ObsWin) is used for drawing and manipulating time-series or observations. The abscissa (X axis) of an Observations Window displays the time over which the observations are plotted, while the ordinate (Y axis) represents their magnitude (or intensity). Each

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observation in *Peranso* is defined by following attributes:

- Time (mostly Julian Date, JD)
- Magnitude
- Magnitude Error (MagError) [optional]: the error in the magnitude estimate. A MagError value is visually represented as a 'vertical bar' centered around the corresponding magnitude dot in the light curve. The bar extends above and below the observation by the amount of the error. For example, if the magnitude error is 0.1 mag, the total bar height is 0.2 mag, indicating the value is meant to be taken as +/- the amount. Magnitude error values are taken into account when performing a period analysis calculation using the FALC method.
- Use status [optional]. Has a value of 0 or 1 and determines if an observation is considered to be active (1) or inactive (0). Inactive observations are not taken into account when performing a period analysis calculation. Observations can be made active and inactive at every moment, using the mouse and keyboard. An active observation is plotted as a filled circle in an Observation Window. Inactive observations appear as open circles.

Observations are logically grouped in observation sets. Observation sets are typically used to make logical partitions in large volumes of observations, e.g., to partition per night or per observer. *Peranso* offers an extensive set of commands that operate on all observations of an observation set at once (e.g., to average an observation set).

Below is an example of a *Peranso* Observations Window, showing two Observation Sets : one is colored in blue, and displays magnitude errors (as light gray bars). The other is colored in red. The X axis of the ObsWin is labeled *JD* (Julian Date), and represents the time of the observations. The label *2453225.0+* in the lower left part is the **Baseline** time value. All X axis labels have to be read in relation to the Baseline value.

Example : the X axis label 0.5 corresponds to a time value of JD 2,453,225.0 + 0.5 = 2,453,225.5

The Y axis of the ObsWin is labeled *mag* (magnitude), and represents the (differential) magnitude of the observations.

The label *[0.3572, 0.6876]* in the lower right part displays the **mouse coordinates** (time, mag). When the mouse cursor is over an observation, the exact time and magnitude of that observation are shown in the color of the corresponding Observation Set. In addition, the font type of the mouse coordinates changes to 'bold'. If the mouse cursor is not over an observation, then the time and magnitude of the cursor position are shown instead, in a light blue color and using a normal font type. If the observation below the mouse cursor has a Magnitude Error value, then that value is shown as well in the mouse coordinates display. When the Observations Window contains over 100.000 observations, *Peranso* will not attempt to display the exact time and magnitude of the observation under the mouse cursor (for performance reasons). Instead, the mouse cursor position is shown.

The toolbar in the upper part of the Observations Window groups frequently used ObsWin commands. Almost all graphical properties of an ObsWin can be modified by the user.

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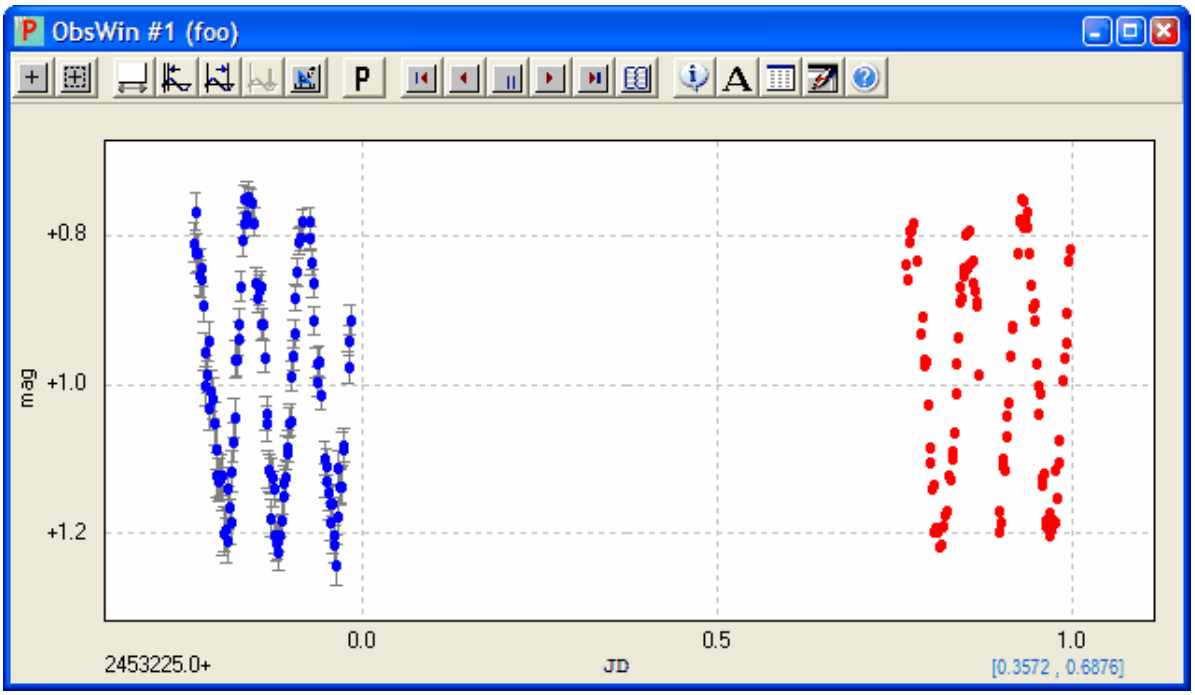

Example Peranso Observations Window

3.1.2 The Period Window (PerWin)

A *Peranso* Period Window (short PerWin) is used for drawing the results of a period analysis, and for doing extensive period analysis work. The abscissa (X axis) of a Period Window displays the time or frequency range over which the period calculations are made. The choice between time domain or frequency domain calculations is made at the start of a period analysis calculation. The default base time in *Peranso* is **days**, which is more typical for variable star work. A user can switch the base time to **hours**, e.g., when making asteroid period calculations. The choice again is made at the start of a period analysis calculation.

The ordinate (Y axis) of a Period Window displays the calculated statistic of the selected period analysis method, or the power spectral density :

- If a statistical method is used for the period analysis, then the Y axis displays the calculated statistic of the selected period analysis method. E.g., in the PDM method the calculated statistic is the PDM 'theta' statistic. In the Renson method, the calculated statistic is the 'theta1' statistic of Renson. In the Dworetsky method, the calculated statistic is a scaled value of the Dworetsky string length.

- If a Fourier method is used for the period analysis, then the Y axis mostly displays the power spectral density values.

The label *[5.9038, 0.1694, 1522.9577]* in the lower right part displays the **mouse coordinates** and consists of 3 parts :

- X axis value expressed in time domain
- X axis value expressed in frequency domain

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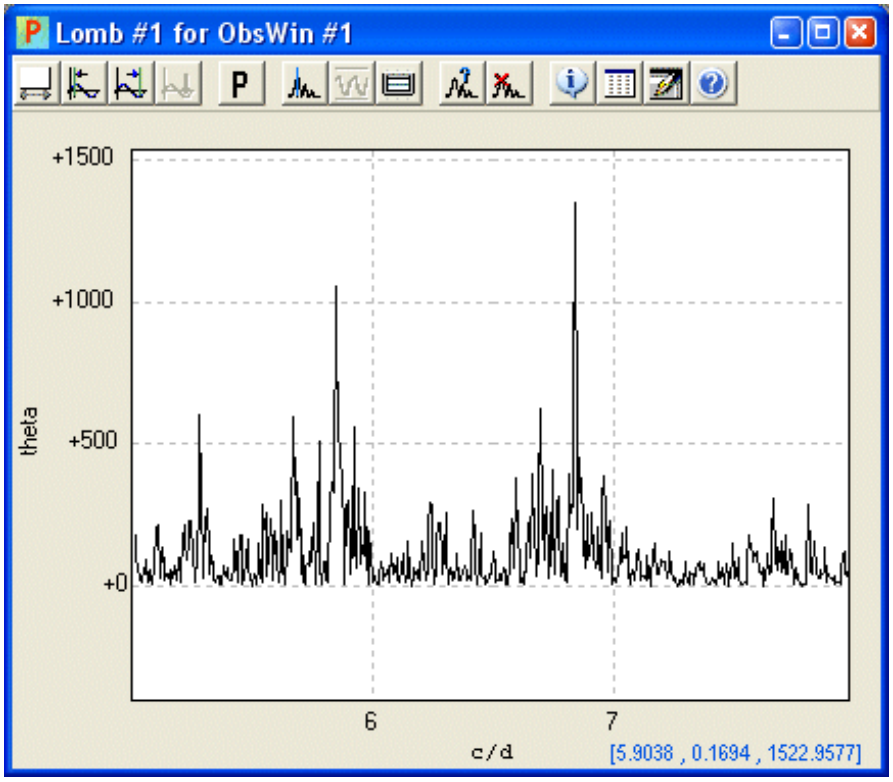
- Y axis value

The toolbar in the upper part of the Period Window groups frequently used PerWin commands. Almost all graphical properties of a PerWin can be modified by the user.

Not all peaks (or valleys) in a Period Window correspond to true periods : some peaks arise from aliasing, others may be harmonics of the main (fundamental) frequency, etc. Even if a period is a true period, it may not be significant. Evidently, *Peranso* offers a series of tools to try to distinguish true periods from artifacts and to determine the significance level of a period.



Example Peranso Period Window

3.1.3 The Phase Window (PhaseWin)

A *Peranso* Phase Window is used for drawing a phase diagram. A phase diagram or folded light curve is a plot of the object's magnitude versus its phase (typically between 0 and 1).

We define the phase as the decimal part of

(t - t0) / P , where

t is the observation time,

t0 is the epoch, and

P is the period.

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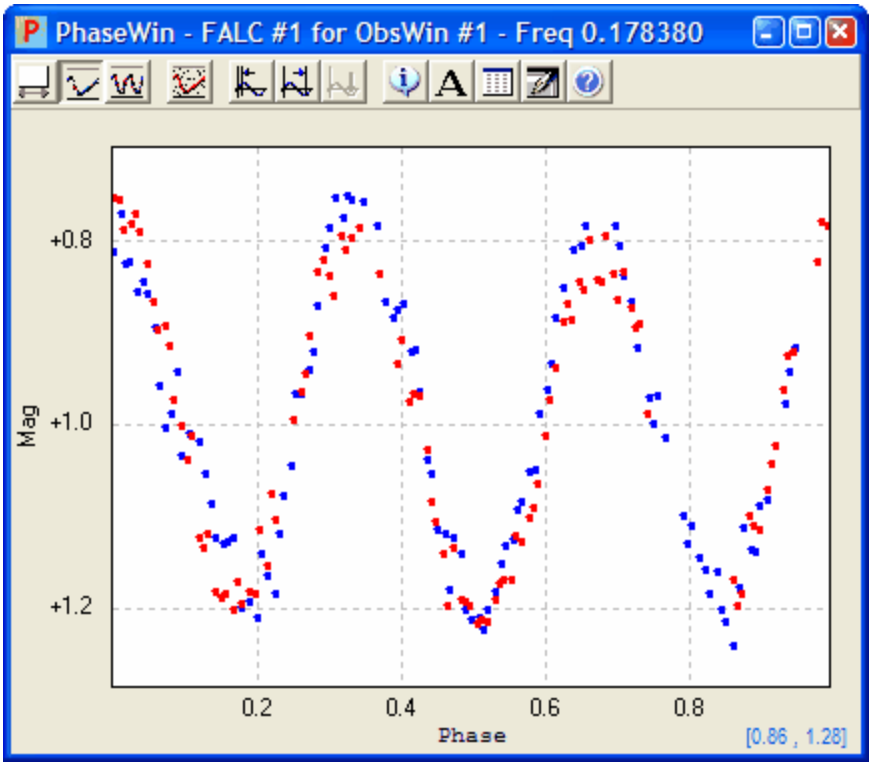
In *Peranso*, we take the JD of the very first observation as the default epoch value. The epoch value can be adjusted by the user.

The label *[0.86, 1.28]* in the lower right part displays the **mouse coordinates** (phase, mag).

The toolbar in the upper part of the Phase Window groups frequently used PhaseWin commands. Almost all graphical properties of a PhaseWin can be modified by the user.



Example Peranso Phase Window

3.2 Using the Mouse and the Keyboard

3.2.1 To zoom in and out using the mouse

To zoom in on any basic *Peranso* window, click and hold the **left** mouse button, while the mouse cursor is over the inner part of the window. While moving the mouse, with the left mouse button still pressed, a rubberband rectangle appears. Release the left mouse button when the rectangle contains the area of interest. The window will be redrawn to depict the selected area.

To zoom out again on a basic *Peranso* window, double click the **left** mouse button. This will redraw the window, zooming out on both the X and Y axis by a factor of 2.
To quickly redraw a basic window showing all data, click the **Full View** button in the toolbar of that window.

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3.2.2 To activate/deactivate observations

To activate or deactivate one observation in an Observation Window, hold the **Shift** button on the keyboard, and (single) click the **left** mouse button when the mouse cursor is close to the observation of interest. *Peranso* will toggle the Use state (active/deactive) of the observation that is nearest to the mouse cursor.

To activate or deactivate a group of observations in an Observation Window, hold the **Shift** button on the keyboard, and meanwhile click and hold the **left** mouse button. A rubberband rectangle appears. Release the left mouse button when the rectangle contains the observations of interest. *Peranso* will toggle the activity state (active/deactive) of all observations within the rubberband rectangle.

You can activate or deactivate an entire Observation Set at once. See section Observation Sets for more details.

3.2.3 To display a context menu

Click the right mouse button anywhere in the inner part of a basic *Peranso* window to display the window's **context menu**. It comprises regularly used commands, that are also accessible through the regular window menus or through the window toolbar.

3.3 Overlays

Overlays are graphical items, drawn on top of a *Peranso* basic window type, and serve multiple purposes. They can be used to mark an interval for extremum calculations, to visualize a polynomial fit through a set of observations, to plot magnitude errors, and so on. *Peranso* supports following Overlays :

- Margin Cursors
- Frequency Cursor
- Extremum Indicator
- Trendline Indicator
- Polynomial Fit
- Magnitude Error Bars
- Model Function
- Residuals

Overlays of Observations Windows are stored to and read from a *Peranso* file.

3.3.1 Margin Cursor

A Margin Cursor is used to mark an interval on the abscissa (X axis) of a *Peranso* window. In case of an Observations Window or Period Window, the marked interval can either be used to define the start and end frequency (or time) for a period analysis, or to define the start and end values for extremum finding. In case of a Phase Window, only the latter option is possible.

- To define (set) a Margin Cursor, click the **Set/unset left margin cursor** or **Set/unset right margin**

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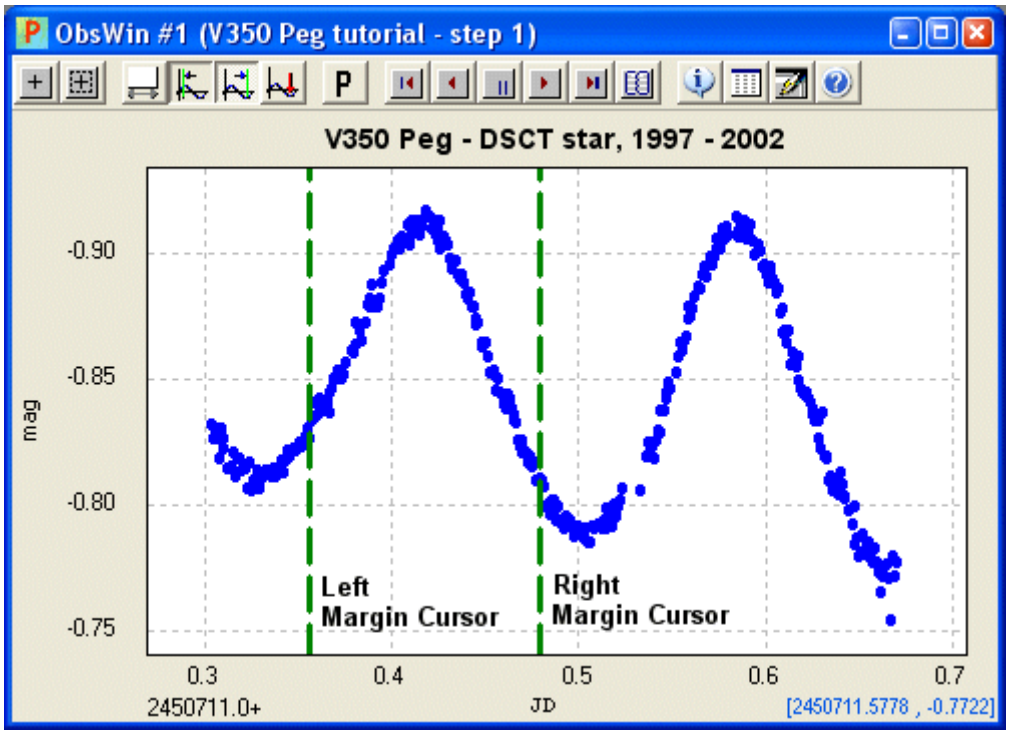
cursor button in the Toolbar. The button will appear as a 'pressed' button. Then move the mouse cursor to the location in the *Peranso* window where you want the left or right Margin Cursor to appear and click the left mouse button.

- To move a Margin Cursor, position the mouse cursor near the Margin Cursor. Then click and hold the left mouse button while moving the mouse. The Margin Cursor will follow the mouse movements. Release the left mouse button to stop.
- To remove (unset) a Margin Cursor, click the **Set/unset left margin cursor** or **Set/unset right margin cursor** button. The button will resume its normal state, and the Margin Cursor disappears.
- To modify the visual appearance of a Margin cursor, use the Properties dialog box.

Margin Cursors are supported in all three basic *Peranso* window types.



Observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

3.3.2 Frequency Cursor

A Frequency Cursor is used to display the time and frequency value at the abscissa (X axis) position of the mouse cursor. It only exists for Period Windows. Its most common use is to locate the dominant period (peak or valley) in a Period Window. In fact, that happens automatically at the moment you define (set) a Frequency Cursor.

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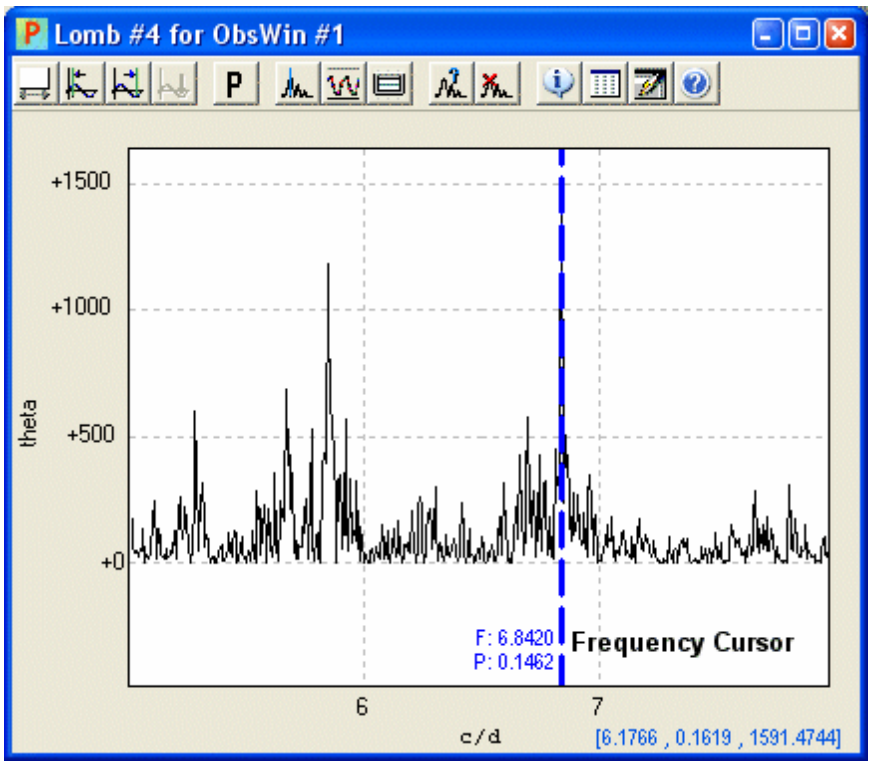
- To define (set) a Frequency Cursor, click the **Set/unset frequency cursor** button in the Period Window Toolbar, or select Show Frequency Cursor from the **Period Analysis** menu. The Frequency Cursor will appear at the location of the dominant period.

- To move a Frequency cursor, position the mouse cursor near the Frequency cursor. Then click and hold the left mouse button while moving the mouse. The Frequency cursor will follow the mouse movements and its values (labels) will be continuously updated. Release the left mouse button to stop.

- To remove (unset) a Frequency Cursor, click the **Set/unset frequency cursor** button, or select Show Frequency Cursor from the **Period Analysis** menu.

- To modify the visual appearance of a Frequency cursor, use the Properties dialog box.



Based on observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

3.3.3 Extremum Indicator

An Extremum Indicator is used to mark the position of an extremum (minimum or maximum) on the abscissa (X axis). It is the result of either a Kwee-van Woerden extremum calculation, or a polynomial fit extremum calculation.

To modify the visual appearance of an Extremum Indicator, use the Properties dialog box.

An Extremum Indicator is supported in all three basic *Peranso* window types.

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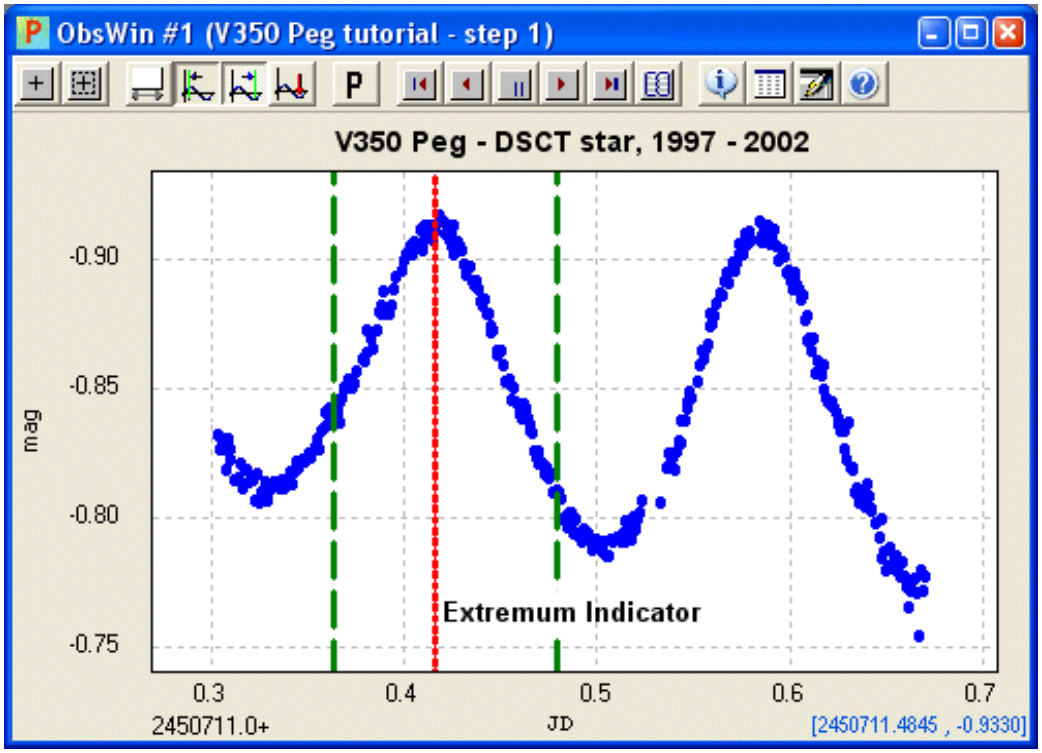

Observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

3.3.4 Trendline Indicator

A Trendline Indicator is used to visualize a linear fit - based on the least squares method - through all observations of an Observations Window. After visualizing the trendline, you may want to detrend the observations.

To modify the visual appearance of a Trendline Indicator, use the Properties dialog box.

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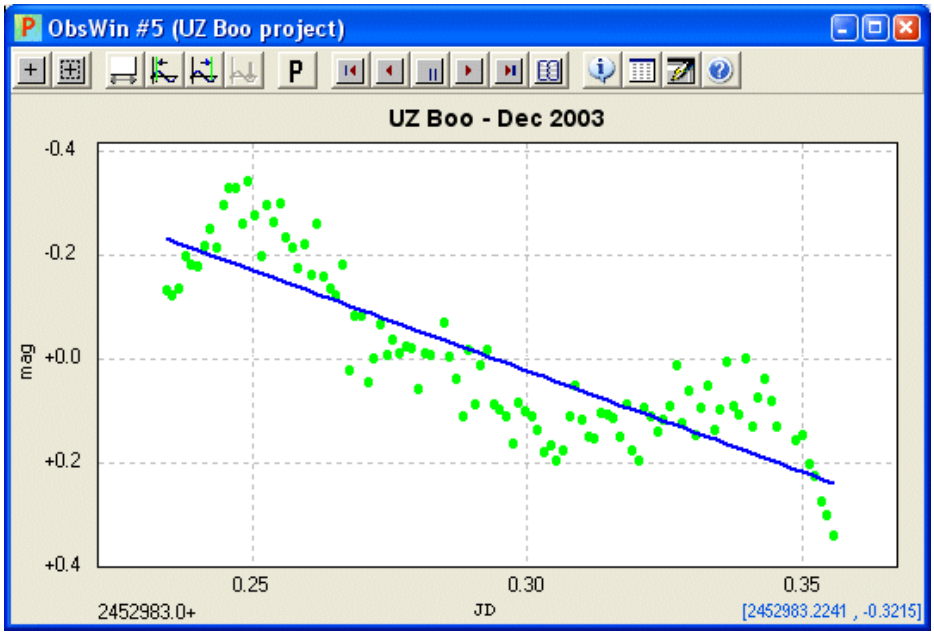
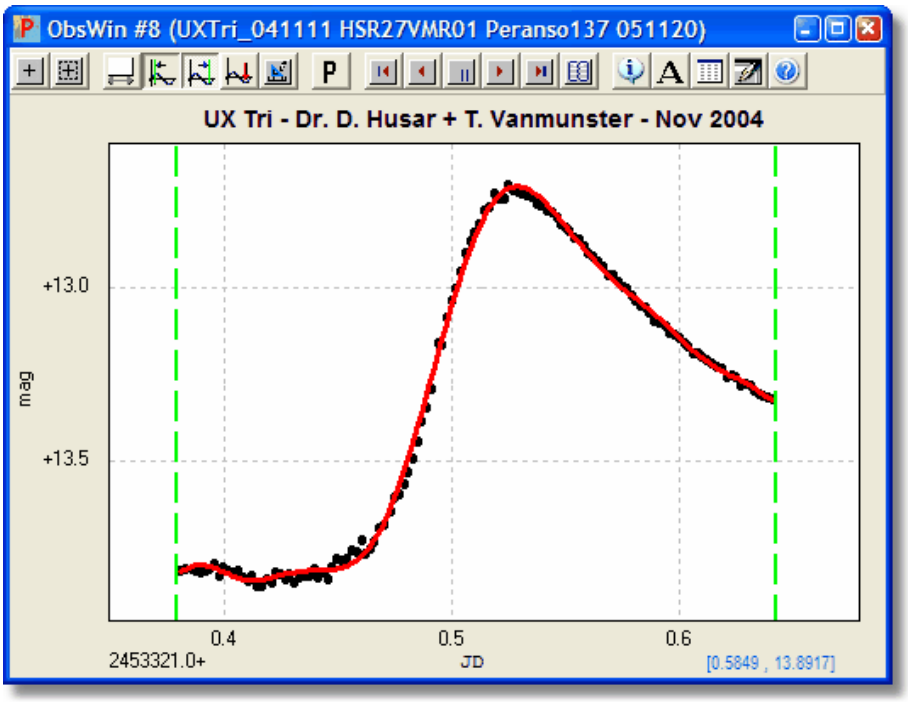


Observations by Tonny Vanmunster, CBA Belgium Observatory.

3.3.5 Polynomial Fit

The Polynomial Fit overlay is part of the Lightcurve Workbench tool and explained in full detail as part of that tool.



Observations of the RRab-type variable star UX Tri, by Dieter Husar and Tonny Vanmunster.

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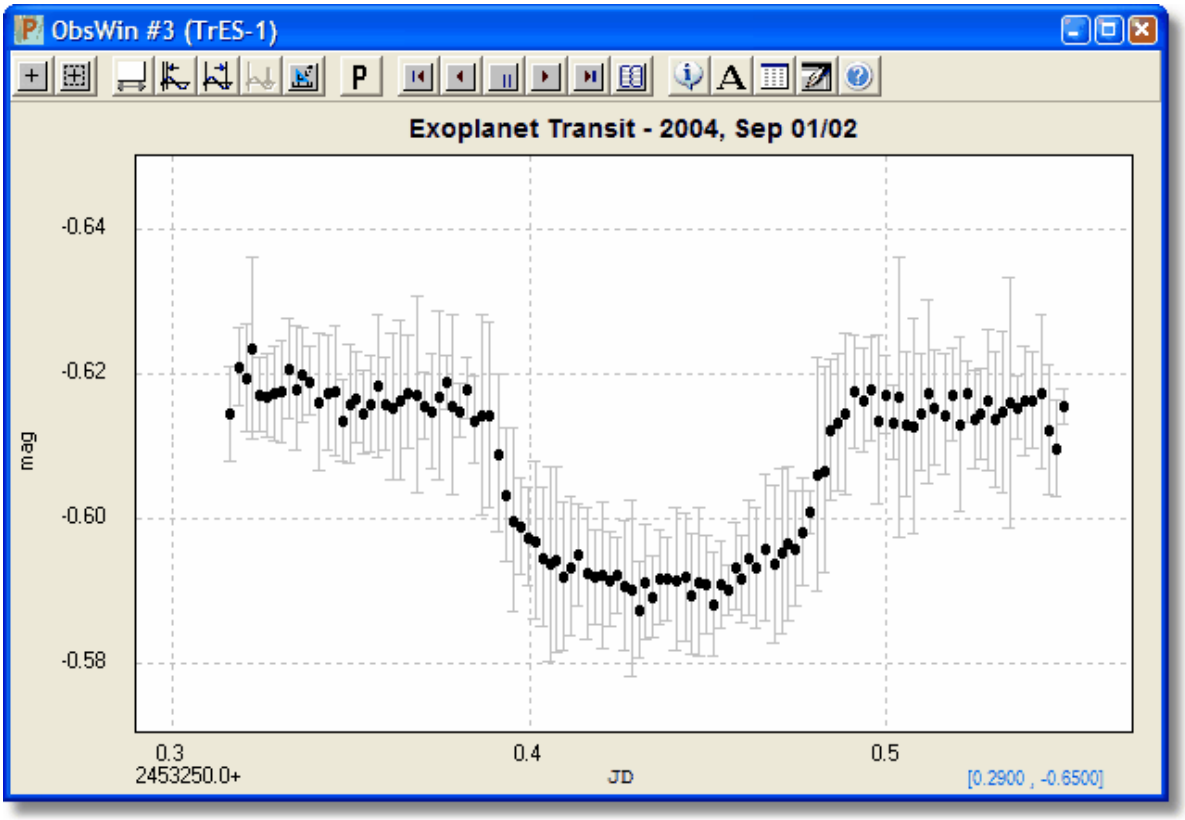
3.3.6 Magnitude Error Bars

The Magnitude Error (MagError) of an observation represents the error in the magnitude estimate. A MagError value is visually represented as a 'vertical bar' centered around the corresponding magnitude dot in the light curve. The bar extends above and below the observation by the amount of the error. For example, if the magnitude error is 0.1 mag, the total bar height is 0.2 mag, indicating the value is meant to be taken as +/- the amount. Magnitude error values are taken into account when performing a period analysis calculation using the FALC method.

This Overlay only exists for Observations Windows.



Observations of exoplanet TrES-1 by Tonny Vanmunster, CBA Belgium Observatory.

3.3.7 Model Function (CLEANest)

A Model Function is used to visualize how one or more periods fit the observations. It only exists for Observations Windows analysed through the CLEANest period analysis method, and can be reached through the CLEANest Workbench. It is explained in full detail as part of the CLEANest tutorial.

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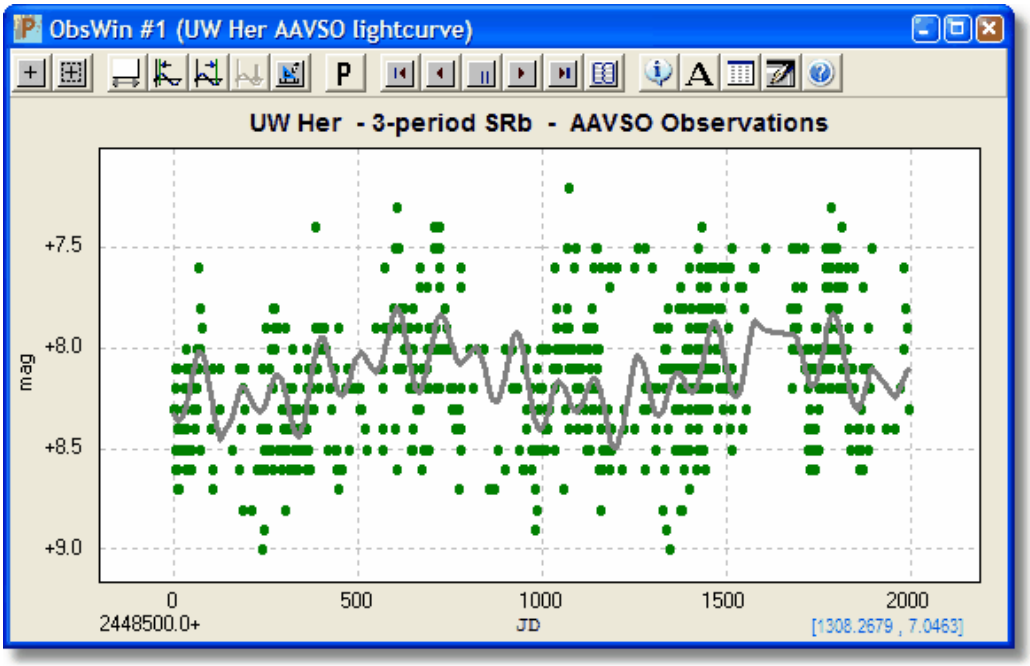
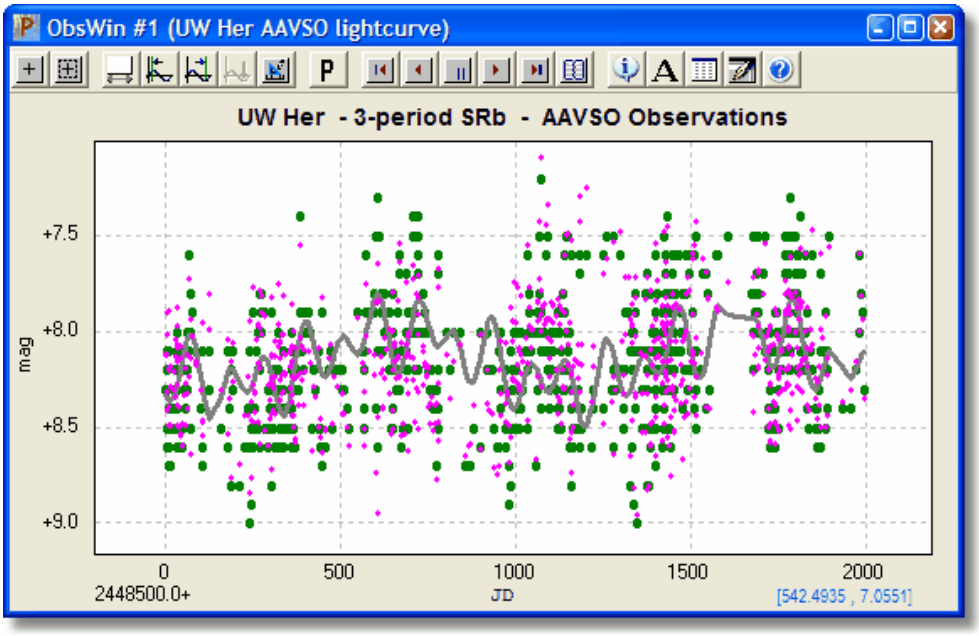


UW Her observations extracted from the *AAVSO International Database.* The Model Function is drawn in dark gray.

3.3.8 Residuals (CLEANest)

Residuals result from subtracting a Model Function from the observations and are used to visualize how adequate one or more periods fit the observations. This overlay only exists for Observations Windows analysed through the CLEANest period analysis method, and can be reached through the CLEANest Workbench. It is explained in full detail as part of the CLEANest tutorial.



UW Her observations extracted from the *AAVSO International Database.* The Model Function is drawn in dark gray, the Residuals in fuchsia.

Part

4 Time-Series Analysis

A substantial part of *Peranso*'s functions deal with the period analysis of astronomical data, also called time-series analysis. Although this user manual is not meant to be an introduction to period analysis, we want to spend a few minutes to present some background information about this topic.

A time-series is a series of observations (or measurements, data) taken at different times. E.g., the brightness estimates of a variable star form a time-series. We thus obtain a set of data pairs (t_i, x_i), where t is the time and x is the observation (data value). We assume that t is error free, and that x is a combination of the true signal, plus some error.

Time-series analysis is the application of mathematics to quantify the variation of the data, i.e. we attempt to find some periodic behaviour in the data. Through this periodic behaviour, we ultimately want to learn something about the physics of the phenomenon represented by the sequence of observations. If we succeed to find a mathematical model that fits the observations, we may even try to predict the future behaviour of the system.

Time-series analysis isn't a field unique to astronomy, but it is used for many other applications, such as stock market analysis, economic forecasting, manufacturing engineering, and so on.

For an excellent introduction to time-series analysis in astronomy, presenting many useful examples, we refer to an on-line presentation by Dr. Matthew Templeton (*American Association of Variable Star Observers, AAVSO*), available at the AAVSO website.

4.1 Classification of period analysis methods

Peranso supports two categories of period analysis methods for **variable stars and asteroids** :

1. Fourier methods : these methods attempt to represent a set of observations with a series of trigonometric functions (sines and cosines, with different periods, amplitudes and phases). They are one of the oldest forms of time-series analysis and are also quite flexible. Fourier methods supported by *Peranso* are : Lomb-Scargle, Bloomfield, Discrete Fourier Transform (Deeming) DFT , Date Compensated Discrete Fourier Transform (Ferraz-Mello) DCDFT, CLEANest and FALC (Harris).

2. Statistical methods : instead of fitting the observation data with trigonometric functions, statistical methods compare points in the observation data to other points at fixed time intervals or "lags" to see how different they are from one another. These methods are very suitable for the analysis of observation data that include non-sinusoidal periodic components.

   Within this category, *Peranso* implements :

   a. *String methods* : these methods fold the observation data on a series of trial periods, and at each trial period the sum of the lengths of line segments joining successive points (the string-length) is calculated. Minima in a plot of string-length versus trial frequency indicate possible periods. *Peranso* implements two string methods : Dworetsky, Renson and Lafler-Kinman.

   b. *Phase Dispersion Minimization* (PDM) : is a classical method of distinguishing between possible periods, by finding the period that produces the least observational scatter ("best phasing of data") around the mean light curve.

   c. *Jurkewich method*

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d. *ANOVA method*

Peranso furthermore implements one specific method for **exoplanet transits** :

- *Edge Enhanced Box-fitting Least Squares* (EEBLS) : this method analyses stellar photometric time series in search for periodic transits by exoplanets, looking for signals characterized by a periodic alternation between two discrete levels, with much less time spent at the lower level.

4.2 Which period analysis method to use ?

Peranso offers a wide variety of methods to analyse periodicities. An obvious question therefore is : which method should I use for what type of object (e.g., variable star). Are some period analysis methods better suited than others for specific types of variable stars or asteroids ?

This is a very difficult question to answer, and unfortunately there is no such thing as the "universal" period analysis method, that is the best choice for whatever type of object. Below, we present some simple guidelines, that may be helpful in answering the question.

Whatever method of *Peranso* you decide to use, always use your eyes and your brain first. Draw a light curve of the observations, and inspect its shape, signature, characteristics, etc. We call this visual inspection. That by itself usually reveals very significant information. A nice example is given in Tutorial 1. Unfortunately, our brain is not faultless, so we have to rely on other approaches too, using mathematical techniques. That's where *Peranso* enters the picture.

The selection of a period analysis method may be influenced by many things :

- the amount of observations
- their spread in time (equally or unequally spaced)
- type of variations (regular-shaped or not)
- expected physical properties of the system (can it be multi-periodic)
- etc

As a rule of thumb :

⇨ *Delta Cepheids* and *RR Lyrae* variables in general can be quite well analysed with the Lafler-Kinman method
⇨ If you expect the system to be *multi-periodic*, use CLEANest.
⇨ If the light curve is highly *non-sinusoidal*, use ANOVA. Otherwise, you may consider DCDFT or CLEANest.
⇨ PDM also is well suited for highly *non-sinusoidal* data with only a few observations over a limited period of time.
⇨ FALC is a de facto standard for *asteroid* period analysis. Try that one first.
⇨ If you're studying *exoplanet transits*, use EEBLS.

In developing *Peranso*, I have studied hundreds of light curves of many different objects. Although there is no "universal" period analysis method, there is one that - in my humble opinion - comes pretty close, and that's ANOVA. I have been amazed by its power to improve peak detection sensitivity and to damp alias periods. Try it out yourself, and see if it suits your data. If not, there's many others to experiment with. Have fun !

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Part V

5 Tutorial 1 : Peranso Quick Start

This tutorial provides a quick introduction to using *Peranso*. It is intentionally kept brief so that you can actually start using the program as quickly as possible. The objective is not to teach you every single detail but to familiarize you with the basic principles and the way the program works.

Once you get used to working with *Peranso* you will also find plenty of more useful help and support in the other sections.

In this tutorial, we'll do a period analysis of the variable star R Leonis (R Leo). With a change in brightness of over 4 magnitudes and an average periodicity of 312 days, this star is categorized as belonging to the Mira-type class of long period variable stars. Since its discovery over 200 years ago, it has become one of the most widely observed variable stars of its class. The observations in this tutorial have been extracted from the *AAVSO International Database* (1).

(1) We acknowledge with thanks the variable star observations from the **AAVSO International Database** contributed by observers worldwide, and used in this research.

5.1 Importing observations in Peranso

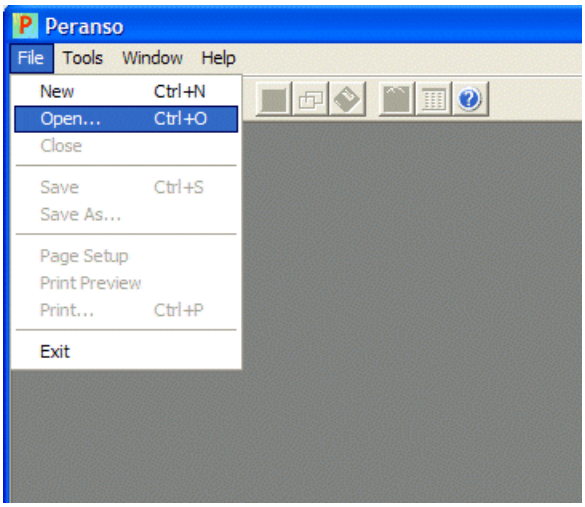
We will first learn how to import observations in *Peranso*, by loading them directly from a text file, with a simple 2-column structure. One column contains the Julian Dates (JD) of the observations, the other column their magnitudes.

We will later see how to import observations in *Peranso* from other text files or by using the Microsoft Windows clipboard.

1. Launch *Peranso* by selecting the program from the All Programs folder of your Windows Desktop.

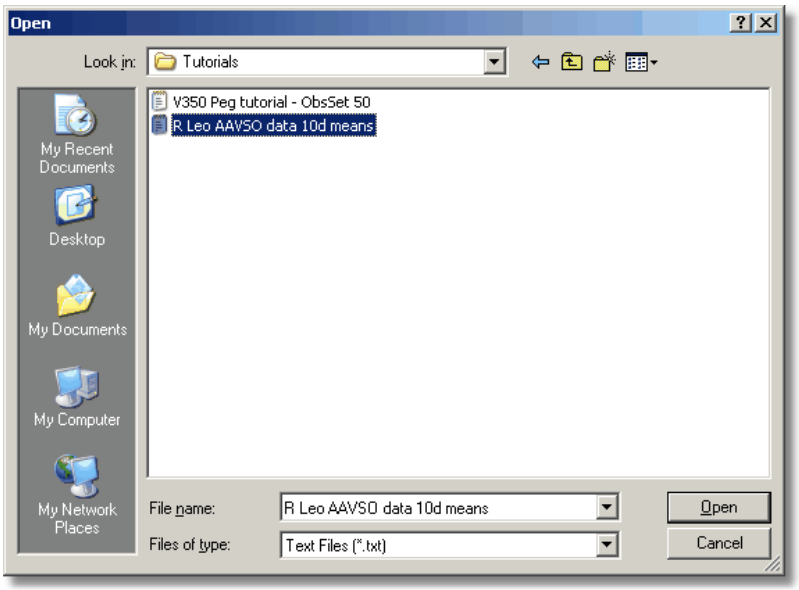
2. This brings up the *Peranso* Desktop Window.

3. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box.



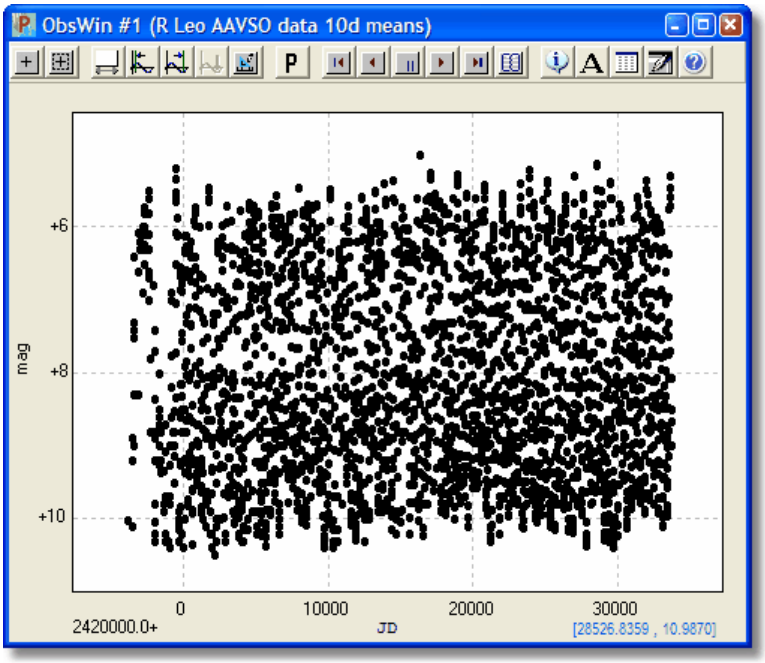
4. Navigate to the Peranso *Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located.

5. Set the **File Type** in the **File Open** dialog box to "*Text Files (*.txt)*"



6. Select the file "*R Leo AAVSO data 10d means.txt*" and click the **Open** button in the **File Open** dialog box.

7. This creates an Observations Window (ObsWin) with caption "*ObsWin #1 (R Leo AAVSO data 10d means)*". Each dot in the light curve represents a 10 days mean value.



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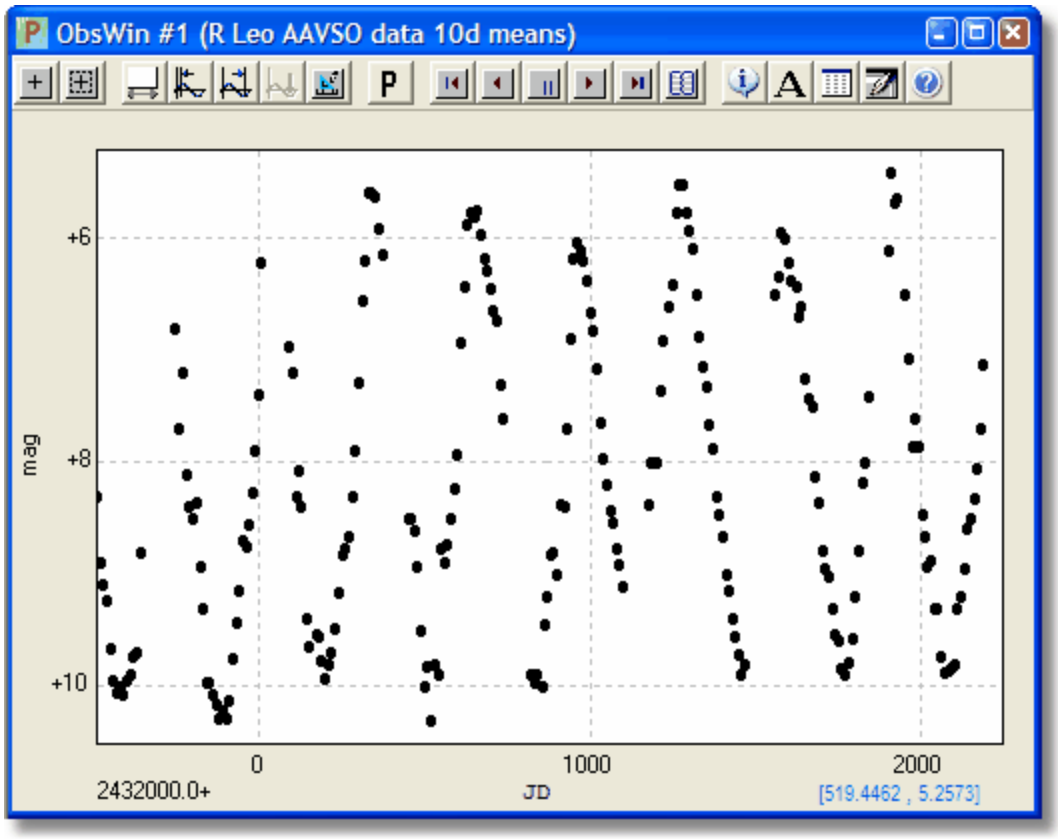
8. As we will see in the next step, we have now loaded 2746 observations of *R Leo* in *Peranso*, covering a time span of more than 100 years. All observations appear in one single Observation Set (ObsSet).

   Let's start with a visual inspection of the light curve. We will therefore zoom in on the Observations Window. Move the mouse cursor to the middle of the window, click and hold the left mouse button. While moving the mouse, with the left mouse button still pressed, a rubberband rectangle appears. Release the left mouse button when the rectangle contains the area of interest. Repeat the zoom operation until you get a window more or less similar to the one below.



9. The data indicate a variation with a periodicity of about 300 days - a value that we will use to start a period search in the next step. Each dot in the light curve represents a 10 days mean value. It therefore is most likely that aliasing with a period of 10 days will appear when we do a period search. Since observations of *R Leo* become impossible every year at around the same time, it also is very likely that aliasing with a period of 365 days will be present. This, we will further investigate in a next step. To summarize :

   ⇨ we expect a period near 300 days
   ⇨ 10 days aliasing may be present
   ⇨ 365 days aliasing may be present

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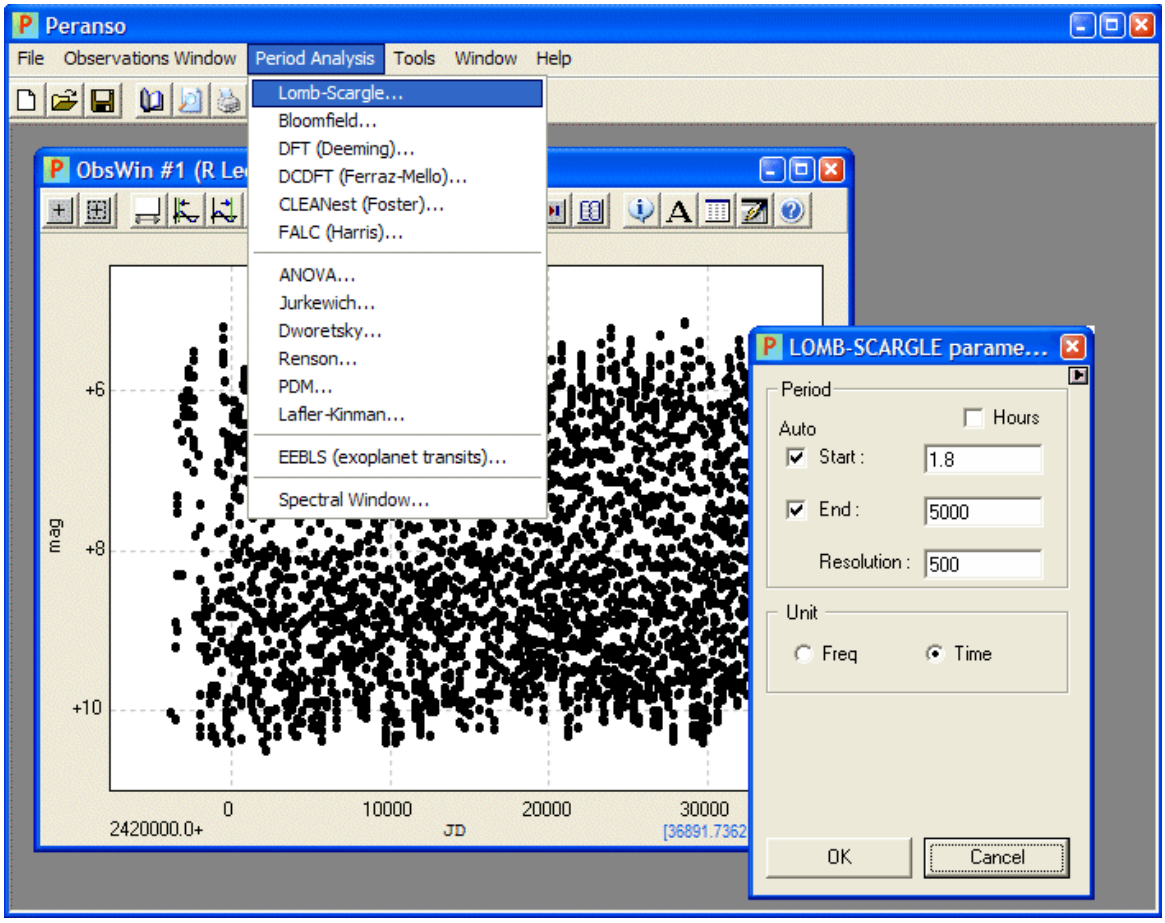
5.2 Performing a Period Search

We will now use one of the many period analysis methods of *Peranso* to determine the period of R Leo.

1. Select **Lomb-Scargle** in the **Period Analysis** menu to display the **Lomb-Scargle Parameters** dialog box.



2. We know from the previous step that a period of about 300 days is present in the data. So, we will do a period scan between 200 and 400 days, using a resolution of 500 points - meaning that we divide the scan interval in 500 equidistant steps, and we do a period calculation for each step. So, we execute a Lomb-Scargle calculation for a value of 200, 200.4, 200.8, 201.2, 201.6, ..., 400 days.

   Enter 200 in the **Start** field of the *Period* frame, 400 in the **End** field and 500 in the **Resolution** field. Leave all other entries to their default value. Click the **OK** button to start the period calculation.

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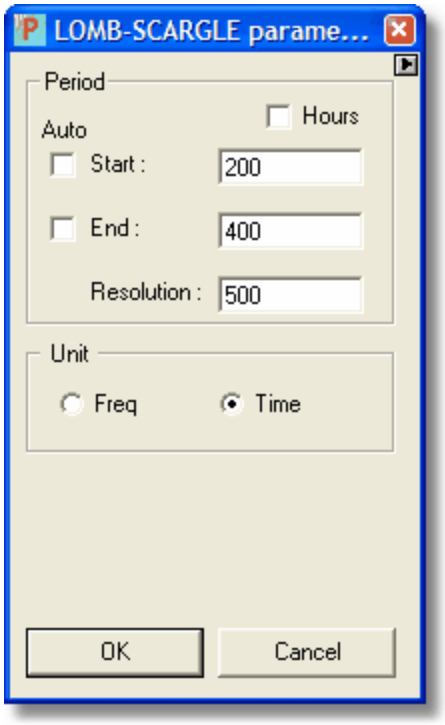
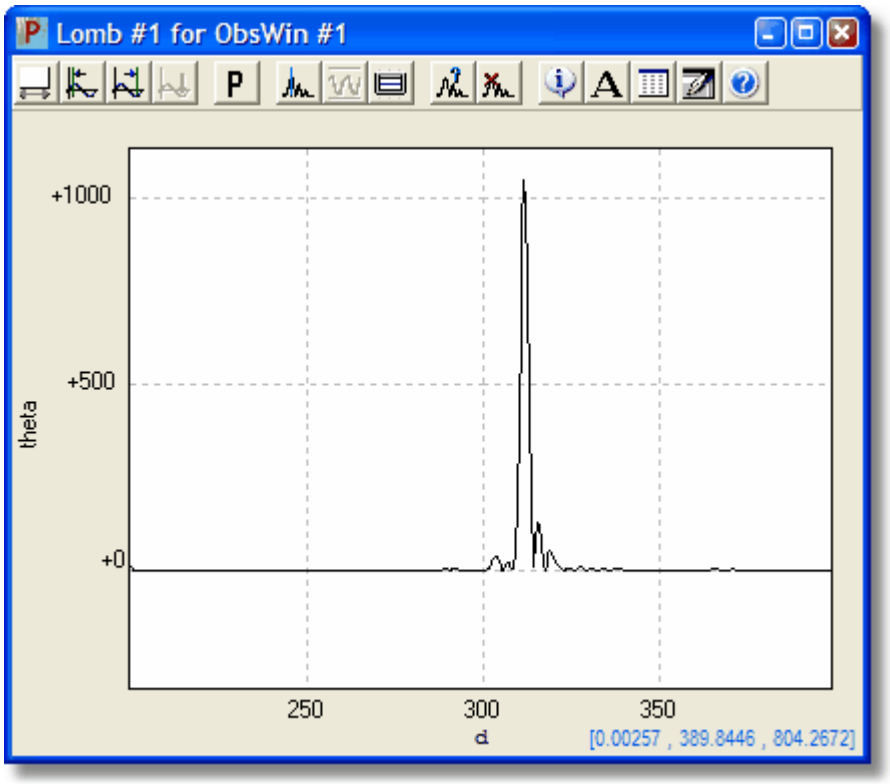


3. This creates a Period Window (PerWin) with caption "*Lomb #1 for ObsWin #1*"



4. The X axis of the PerWin displays the time range (200 - 400 days) over which the period

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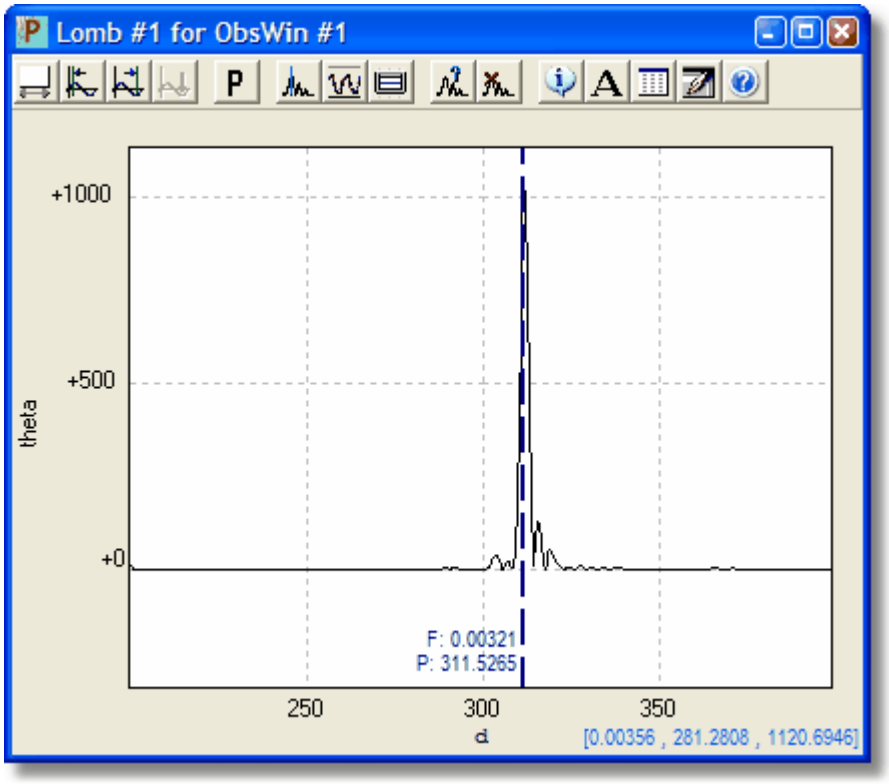
calculations were made. The Y axis displays the calculated Lomb-Scargle statistic for each step in the period analysis. The highest value (a little above 1000) is reached between 300 days and 350 days. We call it the dominant period.

Let's determine the exact value of the dominant period. Select **Show Frequency Cursor** in the **Period Analysis** menu (or click on in the PerWin Toolbar) to display a Frequency Cursor and to position it over the dominant period.



5. The Frequency Cursor appears as a vertical dotted blue line. Next to it are the labels "*F: 0.00321*" and "*P: 311.5265*". These are the Frequency and Time values of the dominant period, i.e. the dominant signal has a frequency of 0.00321 cycles per day (c/d) or a period of 311.5265 days (d). This value is in perfect agreement with literature values. The *General Catalogue of Variable Stars GCVS* v4.2 (Samus 2004) lists a value of 310 days.

6. Move your mouse cursor next to the Frequency Cursor. Click and hold the left mouse button to move the Frequency Cursor in the PerWin. The Frequency and Time values are continuously updated.

   Click twice on to move the Frequency Cursor back to the dominant period.

7. Select **Info** in the **Period Window** menu (or click on in the PerWin Toolbar) to display the **Info Form** dialog box.

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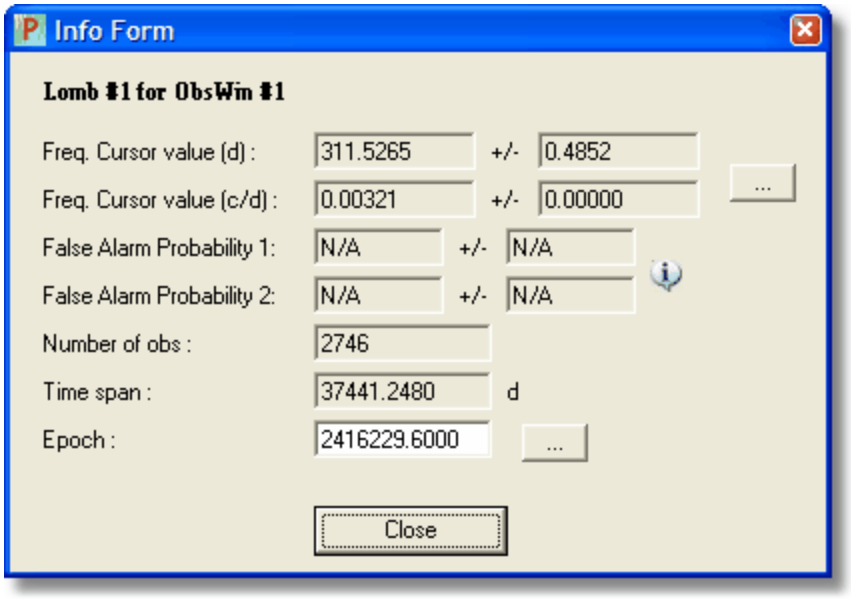

8. The **Info Form** dialog box displays the Time and Frequency value of the dominant period, along with an estimate of the period uncertainty (period error), indicated by the values behind the **+/-** symbol. We thus find that R Leo has a period of 311.5265 +/- 0.4852 days. We furthermore derive that 2746 observations were used in the calculations, covering a time span of 37441 days. Ignore all other fields and **Close** the dialog box.

5.3 Displaying a Phase Window

Finally, we will display a phase diagram by folding all R Leo observations over the dominant period of 311 days, resulting in a plot of the variable's magnitude versus its phase.

1. Select **PhaseWin at Frequency Cursor Value** in the **Period Analysis** menu (or click on in the PerWin Toolbar). This creates a Phase Window (PhaseWin) with caption "PhaseWin - *Lomb #1 for ObsWin #1 - Freq 0.00321*"

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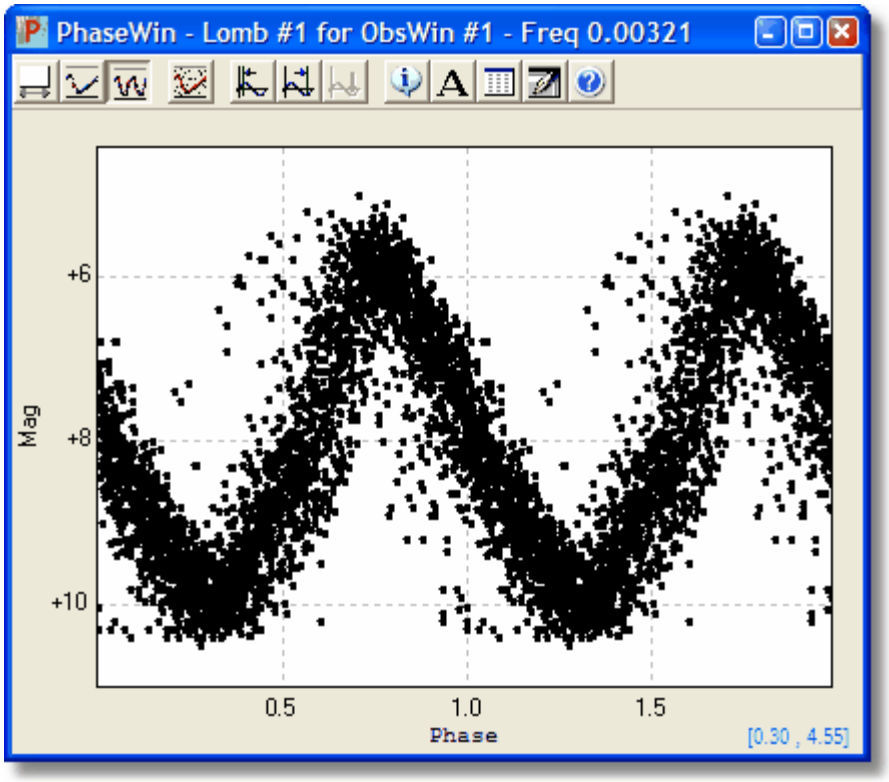

2. The PhaseWin shows a quite typical Mira-type long-period variable star phase diagram. We furthermore note that R Leo varies between approx. magnitude 5.8 and 10.0.

5.4 Checking Aliasing with a Spectral Window

1. Before finally concluding on the period of 311.5 days, we have to do one last check : we have to demonstrate that this period can not be the result of aliasing, i.e. a false peak caused by the observing rate.

   We will create a Spectral Window which exactly calculates the pattern caused by the structure of gaps in the observations. It is not a true Fourier spectrum for *R Leo*, but indicates what peaks in a Period Window are artifacts of the 'sampling rate'. We already know from a previous step that we may expect to see aliasing at 10 days and 365 days.

   Select **Spectral Window** in the **Period Analysis Menu** of the Observations Window, to display the Spectral Window dialog box. Enter the parameters shown below and press **OK** to calculate the Spectral Window.

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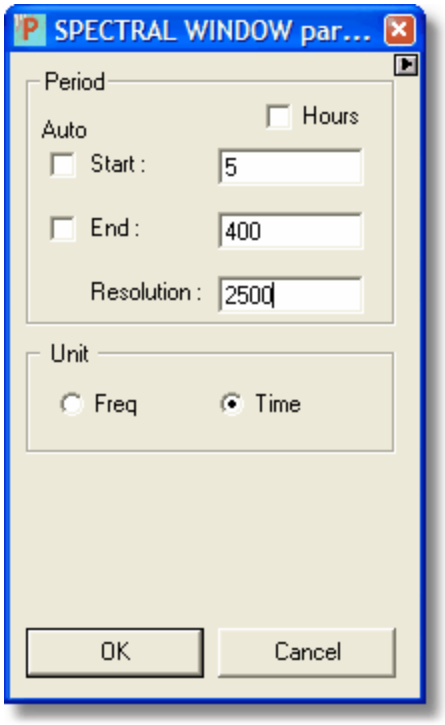
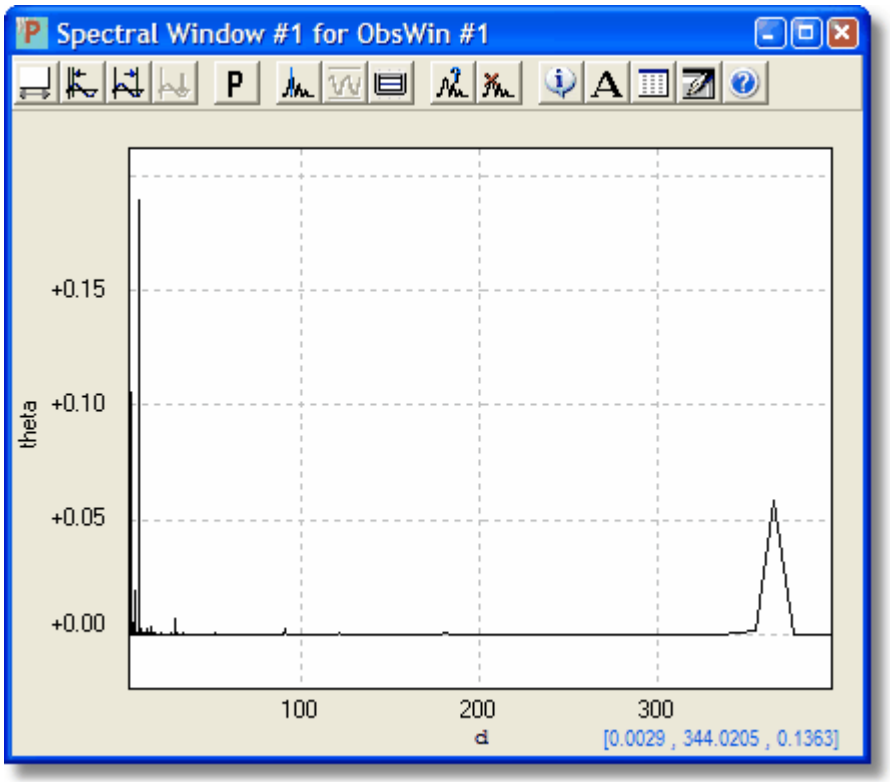


2. This creates a Period Window with caption "*Spectral Window #1 for ObsWin #1*". We easily recognise two peaks in the window : one near 10 days and another near 365 days, as predicted. We observe no peak near 311.5 days, so the *R Leo* period found in this tutorial is not the result of any 'observing rate'.



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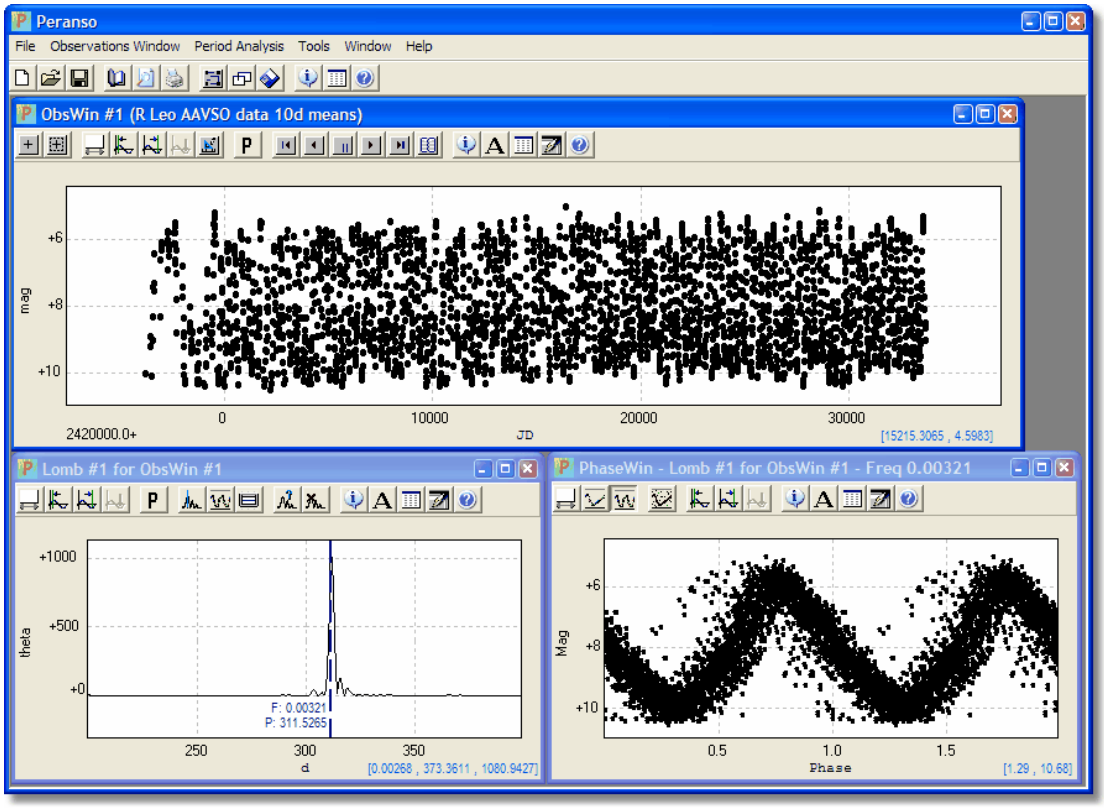
5.5 Saving your analysis results to file

Evidently, we want to preserve our R Leo analysis efforts by saving them to file.

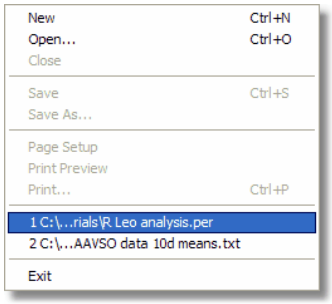
1. The final result of all previous steps yields a *Peranso* desktop looking more or less as follows



2. Select **Save** in the **File** menu (or click on in the main Toolbar) to display the **Save As** dialog box. Select the folder in which you want to store your analysis results, and enter a file name (e.g., "R Leo analysis.per"). Then click the **Save** button to write the file.

3. Select **Exit** in the **File** menu to quit *Peranso*.

4. To reload your R Leo analysis results at a later stage, simply launch *Peranso* and click the **File** menu. At the bottom of the menu (above the **Exit** command) is a list of recently used files. Select your file from the list.



Part

6 Tutorial 2 : Finding Multiple Periods in a Delta Scuti star

This tutorial provides a use case to highlight some advanced *Peranso* product features. It is, however, not meant to be a complete product description. It illustrates how to analyse the periodicities in a large set of observations of the Delta Scuti star V350 Peg (1). We will 're-discover' the multi-periodicities of this variable star using the technique of prewhitening. We conclude the tutorial by an advanced analysis of the statistical significance (False Alarm Probability) of the identified periods, and of their uncertainty (Period Error).

(1) Observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

6.1 Working with Observation Sets

1. Launch *Peranso* by selecting the program from the All Programs folder of your Windows Desktop.

2. This brings up the *Peranso* Desktop Window.

3. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box.

4. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*V350 Peg tutorial – step 1"* and click the **Open** button.

5. This loads the contents of the file and creates an Observations Window (ObsWin) with caption "*ObsWin #1 (V350 Peg tutorial - step 1)*"

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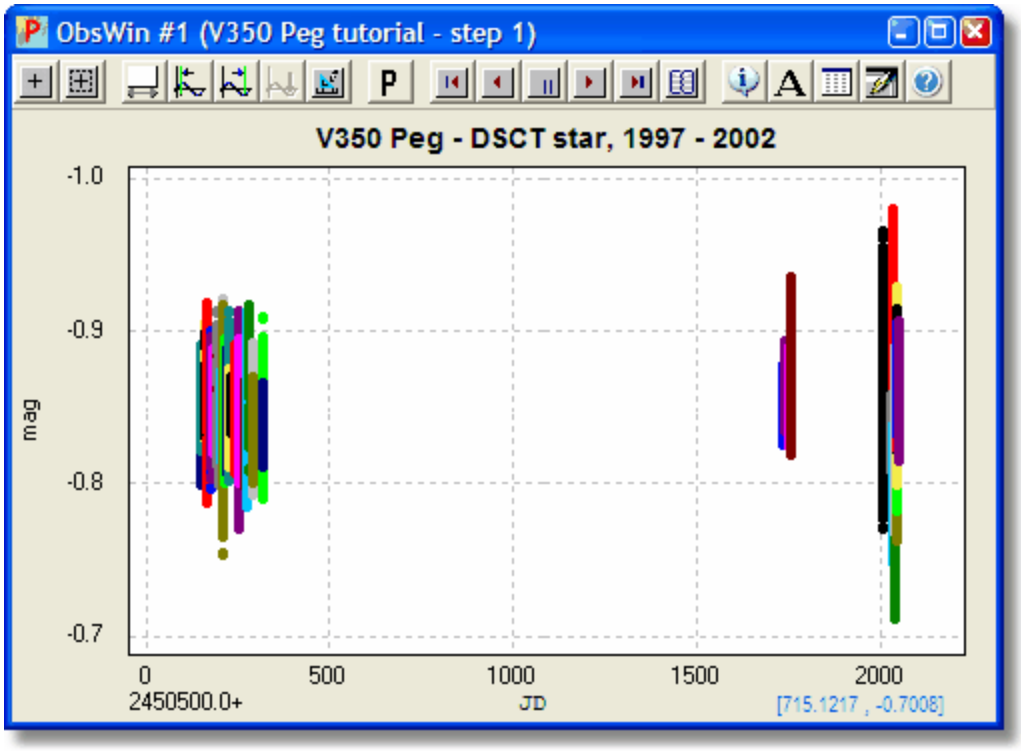
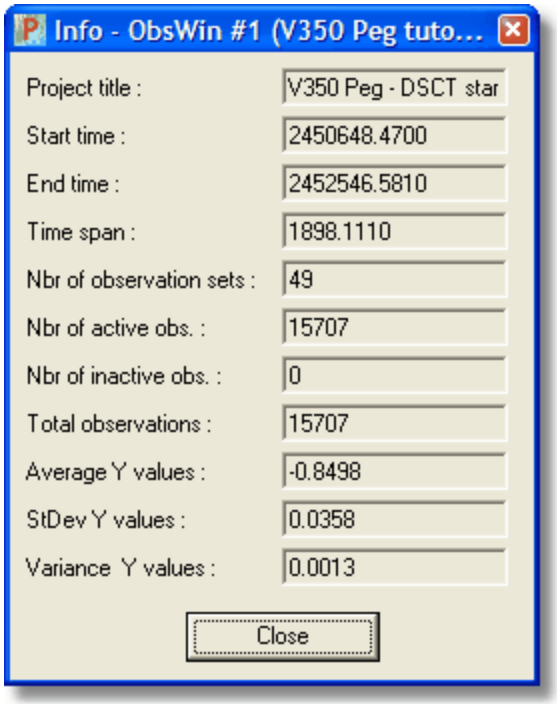


6. The ObsWin contains a large number of observations of the Delta Scuti star V350 Peg. Observations are grouped in Observation Sets (hereafter, ObsSets). ObsSets are drawn in distinctive colors. Select **Info** in the **Observations Window** menu (or click on in the ObsWin Toolbar) to display the **Info** dialog box.


Info - ObsWin #1 (V350 Peg tuto...
Project title : V350 Peg - DSCT star
Start time : 2450648.4700
End time : 2452546.5810
Time span : 1898.1110
Nbr of observation sets : 49
Nbr of active obs. : 15707
Nbr of inactive obs. : 0
Total observations : 15707
Average Y values : -0.8498
StDev Y values : 0.0358
Variance Y values : 0.0013
Close

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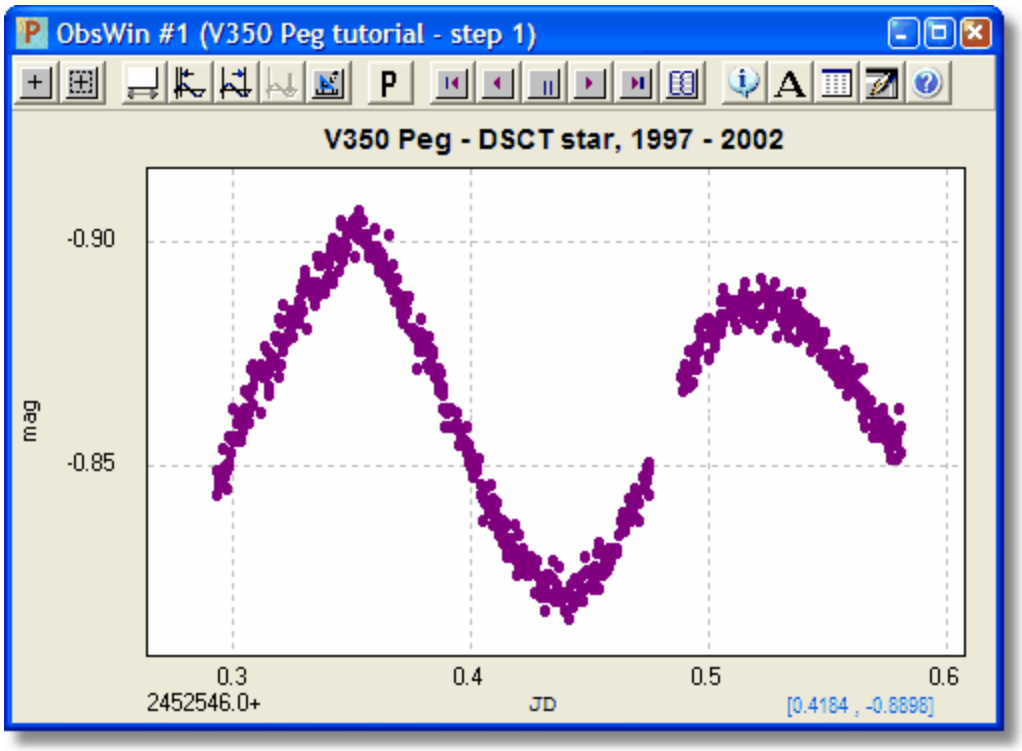
7. The **Info** dialog box lists the name of the *Peranso* project in the field **Project title**, the **Start time** and **End time** of resp. the first and last observation in the ObsWin and the **Time span**, expressed in the X axis units (in this example, days).

   The ObsWin contains 49 observation sets, with a total of 15707 observations. None of these observations are currently inactive.

8. Use the **Navigation** buttons of the ObsWin toolbar to navigate through the individual ObsSets.

9. Click the **Zoom On Last ObsSet** (rightmost) navigation button. The ObsWin shows the last observation set.



10. Use the other **Navigation** buttons to show other ObsSets. Alternatively, select **Observation Sets** in the **Observations Window** menu.

11. Select the command **Zoom On Last** from the menu to show the last ObsSet in the ObsWin. Notice that each time you display another ObsSet, the **Grid** and **Axes annotation** of the ObsWin are automatically adapted, such that grid lines correspond to easy to read values, on both the X axis and Y axis.

    Moving the mouse over the ObsWin results in a continuous update of the **mouse coordinates,** listed in the lower right corner of the ObsWin. The section The Observations Window (ObsWin) provides more details about the mouse coordinates.

12. Move back to the last ObsSet. Then position the mouse cursor over the ObsSet and click the right mouse button to display the ObsWin context menu. Select **ObsSet** to pop up another menu of commands, all related to the current ObsSet. Click on **Properties** to display the **ObsSet**

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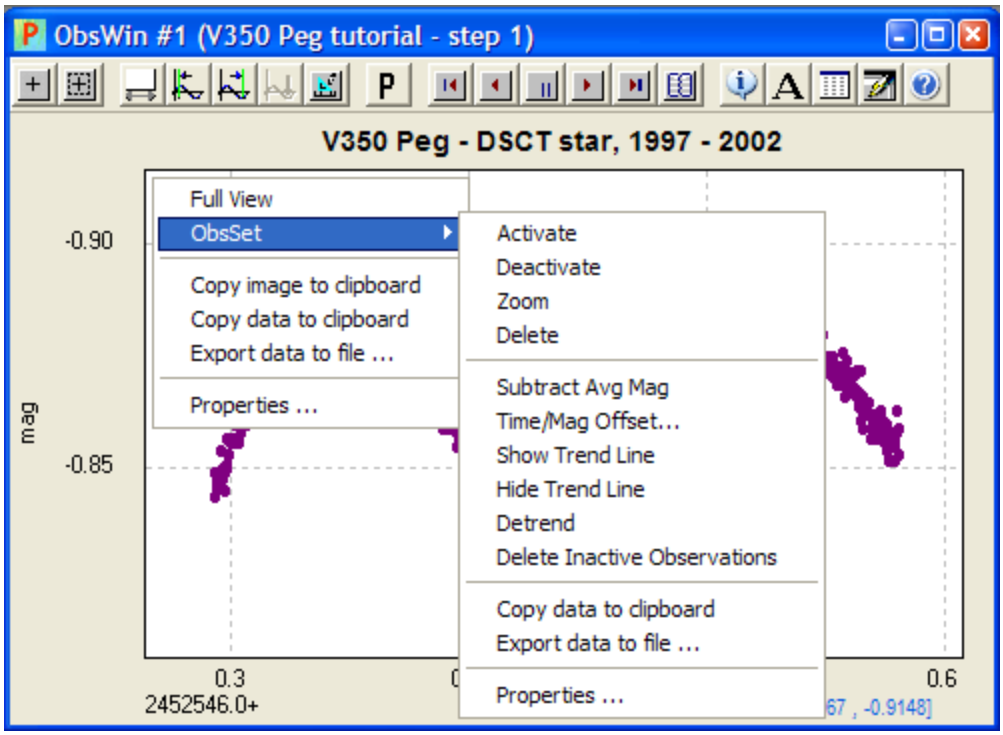
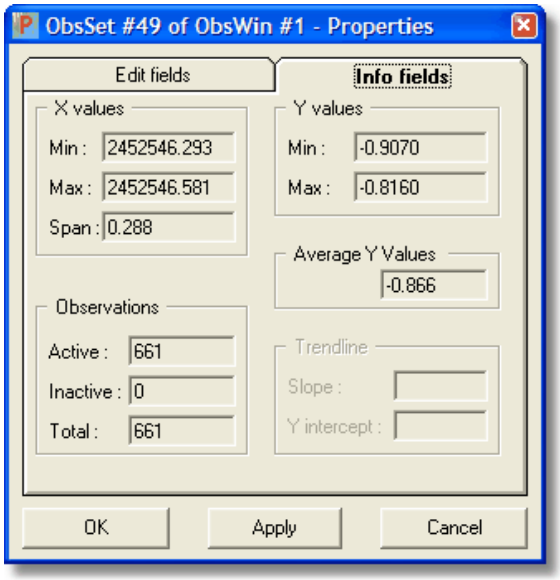
Properties dialog box. A faster way is to click on in the ObsWin Toolbar.

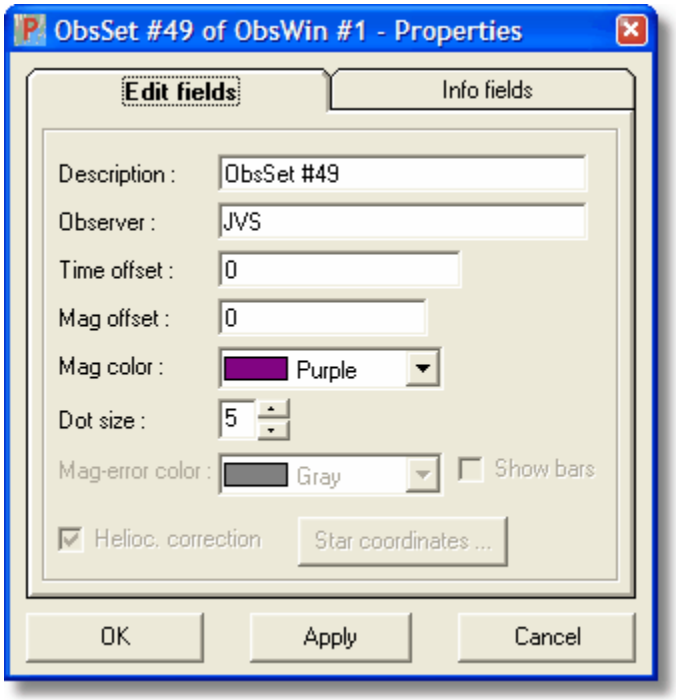


13. The **ObsSet Properties** dialog box contains two tabs, labeled **Edit fields** and **Info fields**. Select the tab **Info fields.** This tab groups relevant information about the ObsSet, including a/o : the X axis values (JD) of the first and last observation in the ObsSet, and similar the Y axis values (mag). The ObsSet contains a total of 661 observations, that are all active.



14. None of the entries in the **Info fields** tab group can be modified. Select the tab **Edit fields**. It provides additional information about the ObsSet, such as the name of the **Observer**, a

Description of the ObsSet, the **Mag color** and **Dot size** used to draw the ObsSet, etc. All fields can be modified by the end user.



15. Click the **Mag color** drop down list to select another color for the ObsSet and click **Apply** or **OK** when done. The ObsWin will be updated accordingly. You can change the **Dot size** of the ObsSet and other fields as well. Experiment !

6.2 Finding an Extremum

In the previous section, we navigated to the last Observation Set in the V350 Peg Observations Window. In that ObsSet, we clearly see two maxima. We will measure the distance (in days) between the two maxima, to derive an initial estimate of the possible period of this Delta Scuti star.

1. To determine the value of the leftmost maximum, we will first draw a Left and Right Margin Cursor, centered around the maximum. To define the Left Margin Cursor, click on the **Set/unset Left Margin Cursor** button in the ObsWin Toolbar. Left click the mouse when it's close to the grid line labeled *0.3*. The left Margin Cursor appears as a dotted green line.

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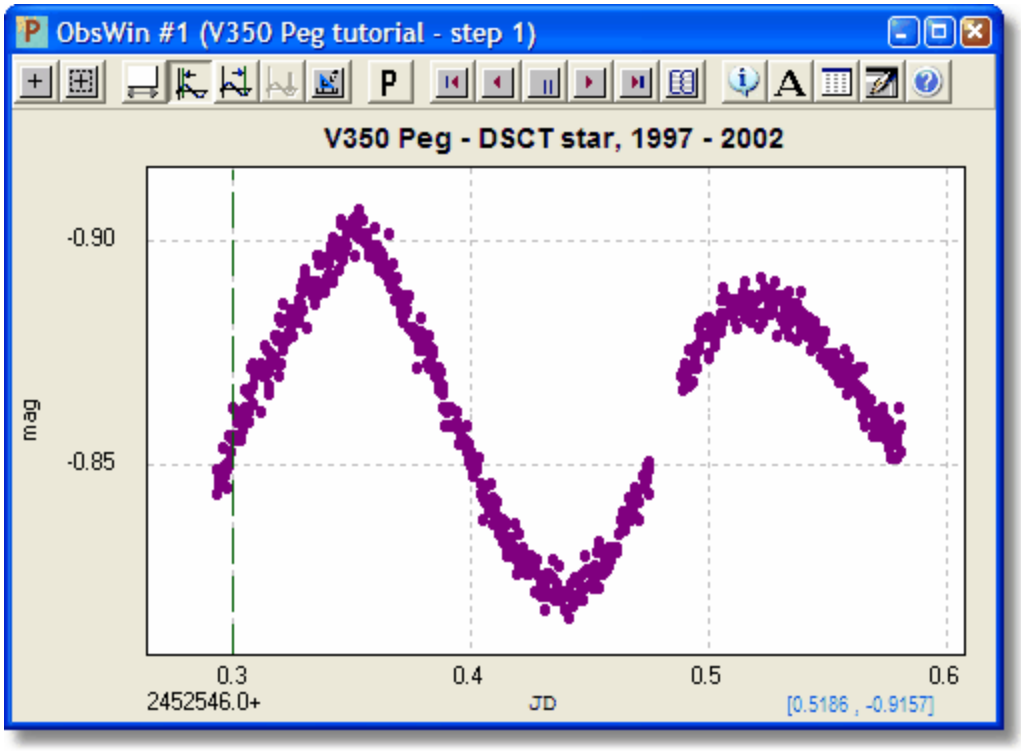
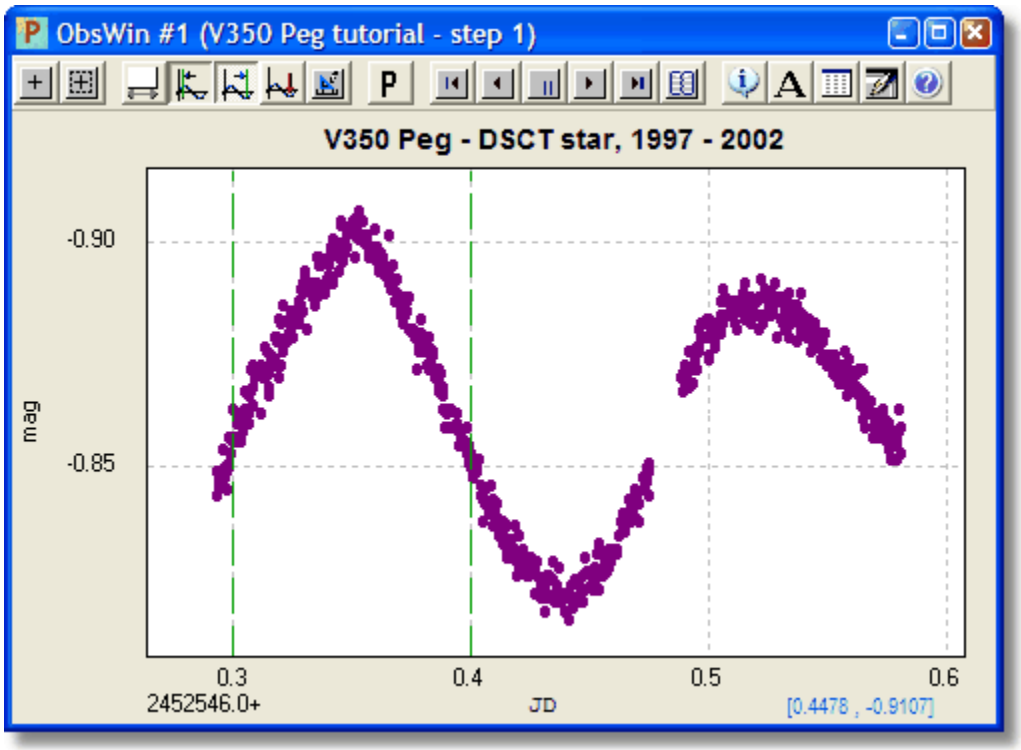


2. We proceed in the same way to define the Right Margin Cursor. Click on the **Set/unset Right Margin Cursor** button in the ObsWin Toolbar. Left click the mouse button when it's close to the grid line labeled *0.4*. The right Margin Cursor appears as a dotted green line.



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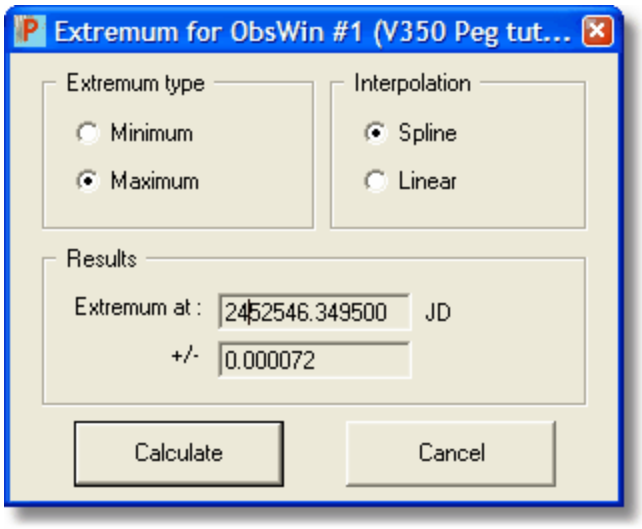
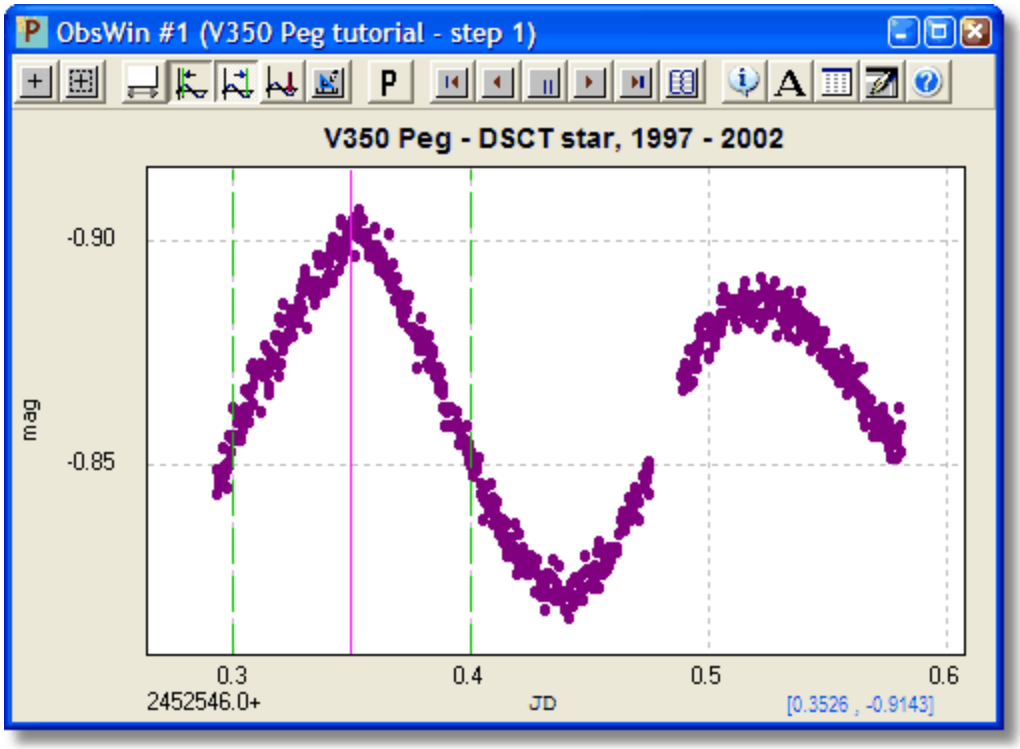
3. Click on the **Find Extremum** button in the ObsWin Toolbar to display the **Find Extremum** dialog box. Select the option **Maximum** in the **Extremum Type** frame and click the **Calculate** button.



4. The results of the calculation are shown in the **Results** frame. The maximum occurs at JD 2452546.349500. It is graphically indicated by a pink line, called an Extremum Indicator.

   Peranso uses the *Kwee-van Woerden* (1) algorithm to calculate extrema. Alternatively, you can determine extrema in *Peranso* using a polynomial fit approach.



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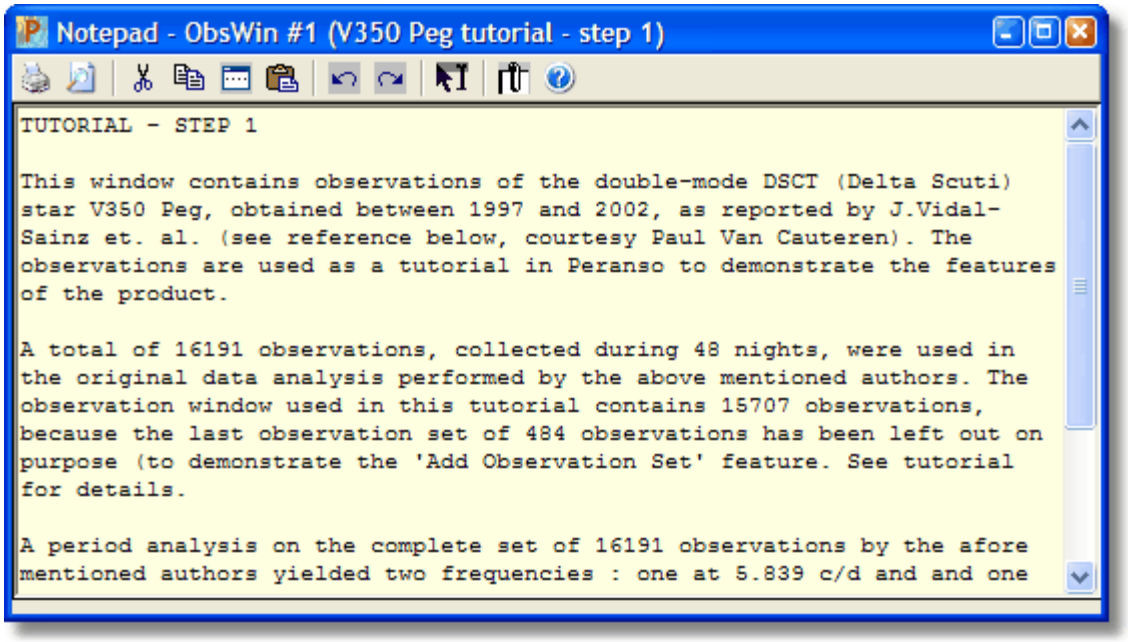
5. Click the **Cancel** button to close the **Find Extremum** dialog box and to remove the Extremum Indicator. Click on the **Set/unset Left Margin Cursor** and **Set/unset Right Margin Cursor** buttons in the ObsWin toolbar to remove the Margin Cursors.

6. Repeat the above steps to find the extremum of the second peak in the ObsSet. You will find a maximum at about JD 2452546.5213. The difference between the two maxima is 0.17 d or 5.78 c/d. We will use this value as an initial approximation for the period determination further on in this tutorial.

7. Select **Notepad** in the **File** menu (or click on in the ObsWin Toolbar) to display the **Notepad** dialog box. Each basic *Peranso* window has an associated **Notepad,** that you use to annotate the window with free format text. For this tutorial, we already entered a descriptive text in the Notepad. It provides relevant information about the observers of these V350 Peg tutorial data. You can simply type in additional text or modify the contents of the **Notepad**, more or less in the same way (albeit more limited) as you operate a word processor.


Notepad - ObsWin #1 (V350 Peg tutorial - step 1)
TUTORIAL - STEP 1
This window contains observations of the double-mode DSCT (Delta Scuti) star V350 Peg, obtained between 1997 and 2002, as reported by J.Vidal-Sainz et. al. (see reference below, courtesy Paul Van Cauteren). The observations are used as a tutorial in Peranso to demonstrate the features of the product.
A total of 16191 observations, collected during 48 nights, were used in the original data analysis performed by the above mentioned authors. The observation window used in this tutorial contains 15707 observations, because the last observation set of 484 observations has been left out on purpose (to demonstrate the 'Add Observation Set' feature. See tutorial for details.
A period analysis on the complete set of 16191 observations by the afore mentioned authors yielded two frequencies : one at 5.839 c/d and and one

(1) Kwee, K., van Woerden, H., 1956, Bulletin of the Astronomical Institutes of the Netherlands BAN, Vol XII, 464.

6.3 Adding an Observation Set to an ObsWin

In the first section of this tutorial, we learned that the ObsWin contains 15707 observations of V350 Peg. However, the **Notepad** window of the previous section mentions a total of 16191 observations. The missing 484 observations were left out of the file "*V350 Peg Tutorial – step 1*" on purpose.

We will now add the missing Observation Set to the ObsWin.

1. The Peranso Tutorials folder contains a file "*V350 Peg tutorial – ObsSet 50*". It is a 2-column (JD,

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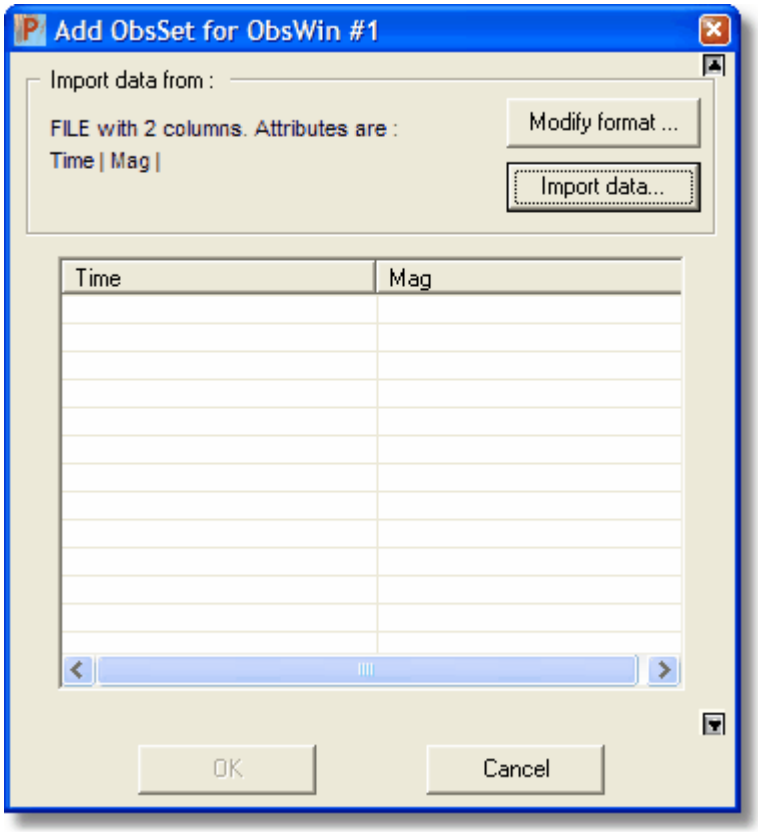
mag) text file, with all missing V350 Peg observations. There are 2 ways to add these observations to the ObsWin as a new ObsSet : either by reading them from file or by pasting them from the Windows clipboard. Steps 2 – 5 describe the file approach, and steps 6 – 12 the clipboard approach.

2. Select **Add Observation Set** in the **Observations Window** menu (or click on in the ObsWin Toolbar) to display the **Add ObsSet** dialog box. It is used to create a new ObsSet and to add it to the ObsWin.



3. The **Import data from** frame indicates that we are ready to read observations from a **FILE with 2 columns**, with attributes Time and Mag. Click on the **Import data** button to display the **File Open** dialog box. Browse to the Peranso Tutorials folder and open the file "*V350 Peg tutorial – ObsSet 50*". This reads the 484 observations from the file into the **Add ObsSet** dialog box.

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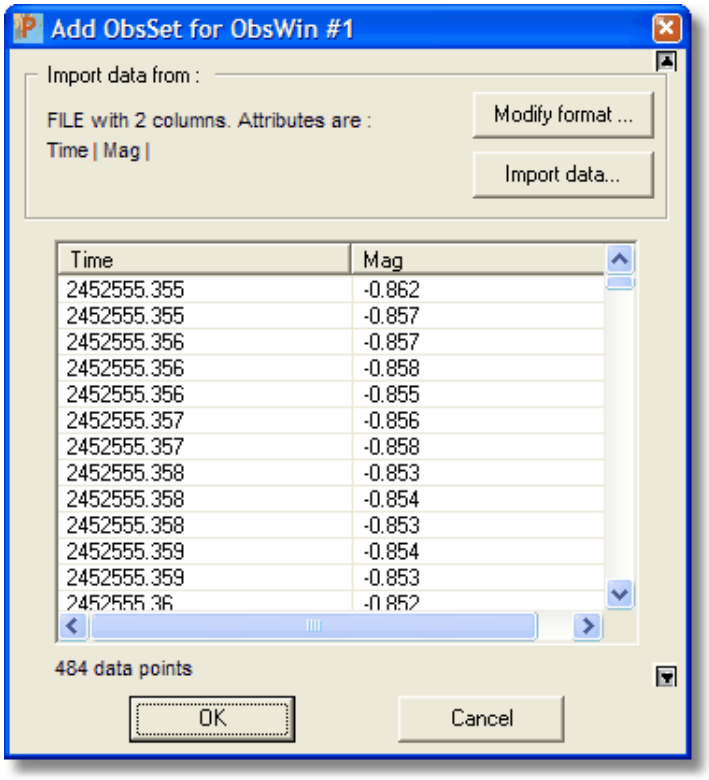
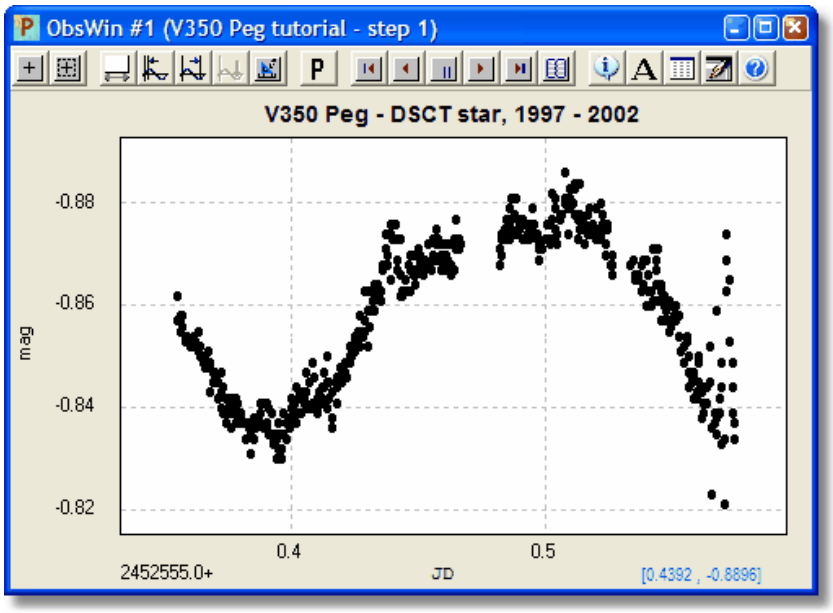


4. Click the **OK** button to create the ObsSet and to add it to the ObsWin. Click on the **Zoom On Last ObsSet** navigation button to display the newly added ObsSet. Click the **Info** button in the ObsWin Toolbar to confirm that the ObsWin now contains 16191 observations.



5. Continue with the next section

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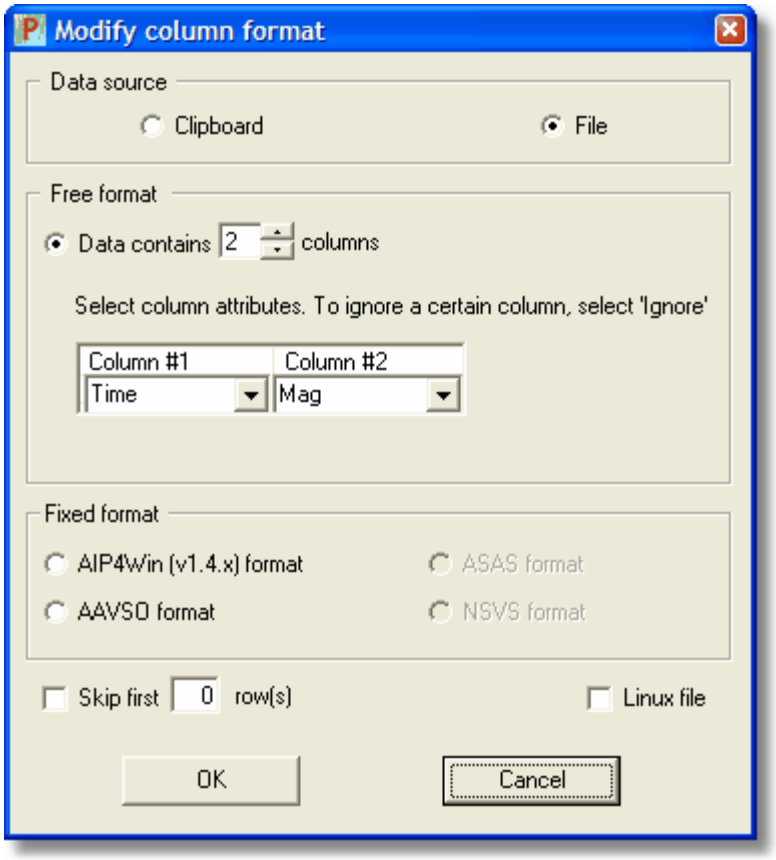
The steps below describe how to create an ObsSet by pasting observations from the Windows clipboard.

6. Open the file "*V350 Peg tutorial – ObsSet 50*" with **Microsoft Excel** or a word processor of choice. Select all observations and copy them to the Microsoft Windows clipboard.

7. Select **Add Observation Set** in the **Observations Window** menu (or click on in the ObsWin Toolbar) to display the **Add ObsSet** dialog box.

8. The **Import data from** frame remembers our previous selection, which was to read observations from file. To import the observations from the Microsoft Windows clipboard, click on **Modify format.** This displays the **Modify column format** dialog box.



9. Select the option **Clipboard** in the **Data source** frame to indicate that we want to import data from the Microsoft Windows clipboard. The **Free format** frame has the right settings (2 columns, with resp. Time and Mag values). Leave all other entries unchanged and click on **OK**.

   The **Add ObsSet** dialog box now lists the correct data source, so we are ready to **Import data from** a **CLIPBOARD with 2 columns**.

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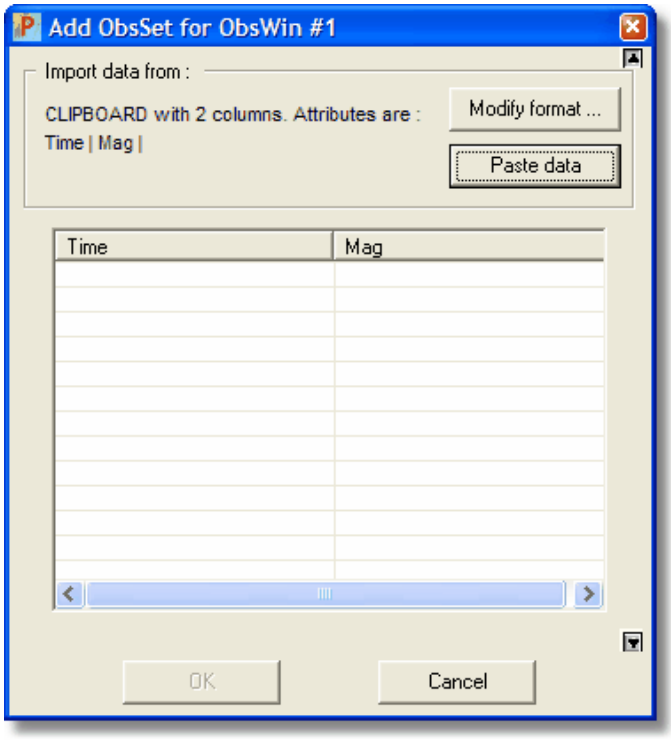
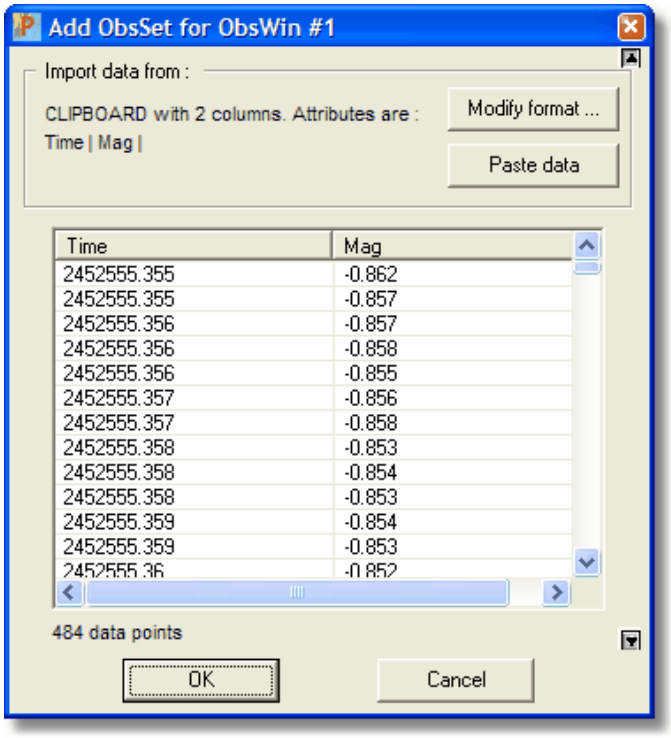


10. Click on the **Paste data** button to paste the 484 observations from the Microsoft Windows clipboard to the **Add ObsSet** dialog box. Click the **OK** button to create the ObsSet and to add it to the ObsWin.



11. Click on the **Zoom On Last ObsSet** navigation button to display the newly added ObsSet. You

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should obtain the same view as in Step 4.

12. Continue with the next section

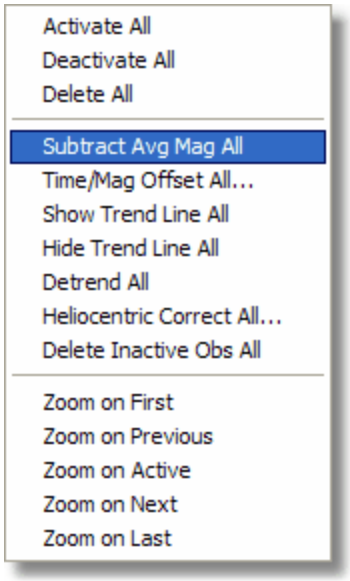
6.4 Aligning the Observation Sets

The alignment of Observation Sets often is critical to finding the right period, since a period determination method can find a different dominant period for different ObsSet alignments. In many cases, you will have to adjust ObsSets so that they mesh well together, before you start the period analysis. The alignment is not always mandatory, and very much depends on the particular characteristics of the observations (e.g., usage of filters, similarities between observing instruments, evolution of light curve over time, etc.).

By adjusting an ObsSet, you move it up or down in relation to the other ObsSets in the ObsWin. By doing this, you can get the data for a given ObsSet to line up with the data from other ObsSets. In some cases (for instance, when working with unfiltered differential variable star magnitudes obtained by different observers) this is not very easy.

Peranso offers two ways of adjusting ObsSets : the Time/Mag Offset command and the Subtract Avg Mag command. This tutorial uses the latter.

1. Select **Observation Sets** in the **Observations Window** menu to pop up a menu with commands that operate on all observation sets of ObsWin at once. Select **Subtract Avg Mag All**.



2. *Peranso* calculates the average magnitude of each ObsSet, and subtracts this average magnitude value from each observation in the ObsSet. The ObsWin is redrawn to show the modified ObsSets.

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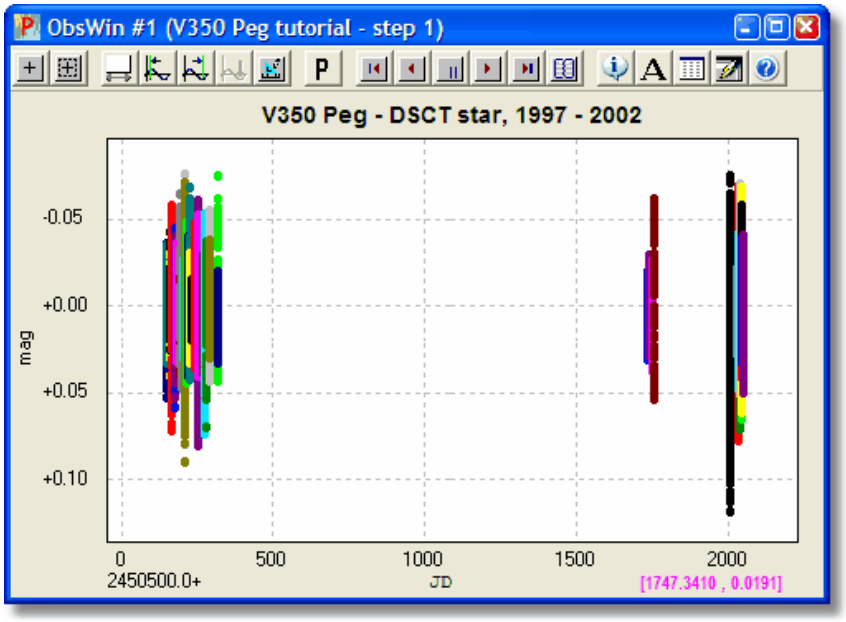
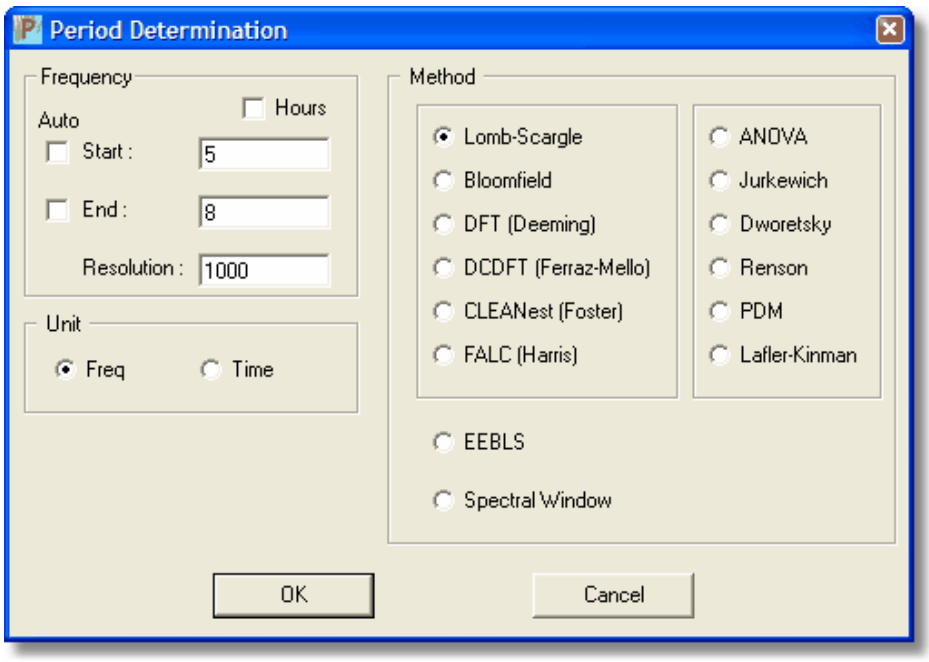


6.5 Finding and refining the dominant period

Peranso offers a wide variety of period analysis methods. In this tutorial, we will use the Lomb-Scargle method to look for the dominant period in the V350 Peg observations.

1. Click on the **Period Determination** button P in the ObsWin Toolbar to display the **Period Determination** dialog box.



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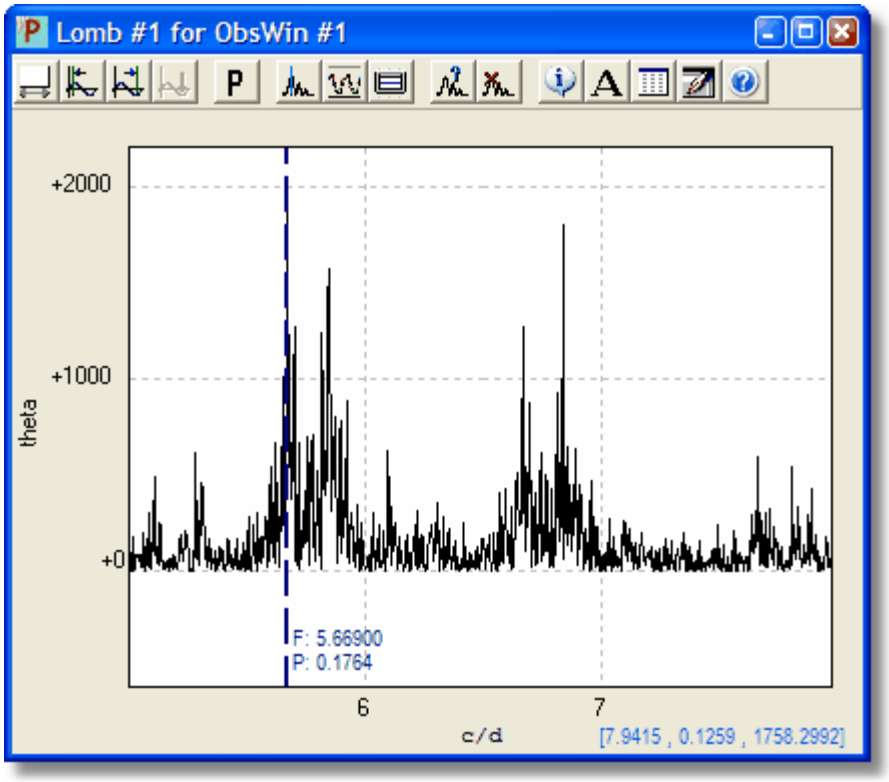
2. The **Method** frame groups all available period analysis methods. Select **Lomb-Scargle**. We know from a previous section in this tutorial that the expected period of V350 Peg is around 5.78 c/d. Select **Freq** in the **Unit** frame and enter 5 in the **Start** text field, and 8 in the **End** text field of the **Period** frame. Enter 1000 in the **Resolution** field. Click **OK** to start the Lomb-Scargle calculations.

3. This creates a Period Window (PerWin) with caption "*Lomb #1 for ObsWin #1*". Follow the instructions from Tutorial 1 to determine the dominant period. You will find a value of 5.6690 c/d.



4. The dominant period has been determined through a period scan between 5 and 8 c/d. To improve the accuracy of the dominant period, we will refine the period analysis by narrowing the period scan and by increasing the scan resolution. Select **Refine Period Analysis** in the **Period Analysis** menu (or click on the Refine Period button P in the PerWin Toolbar) to display the **Lomb-Scargle Parameters** dialog box. Enter a start value of 5.5, an end value of 6.5, and a resolution of 2500. Then click **OK** to start the period calculations.

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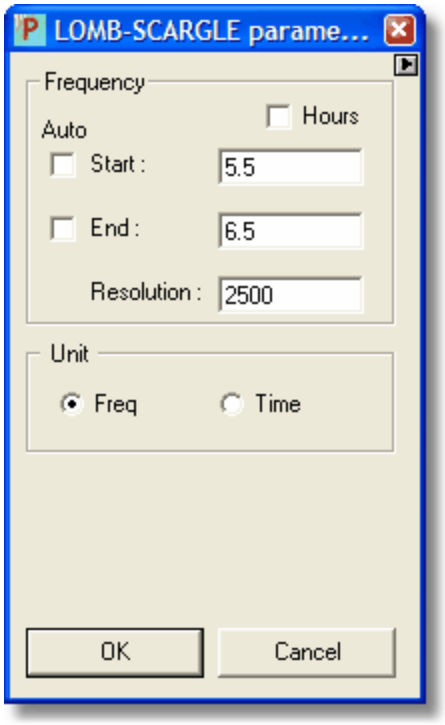
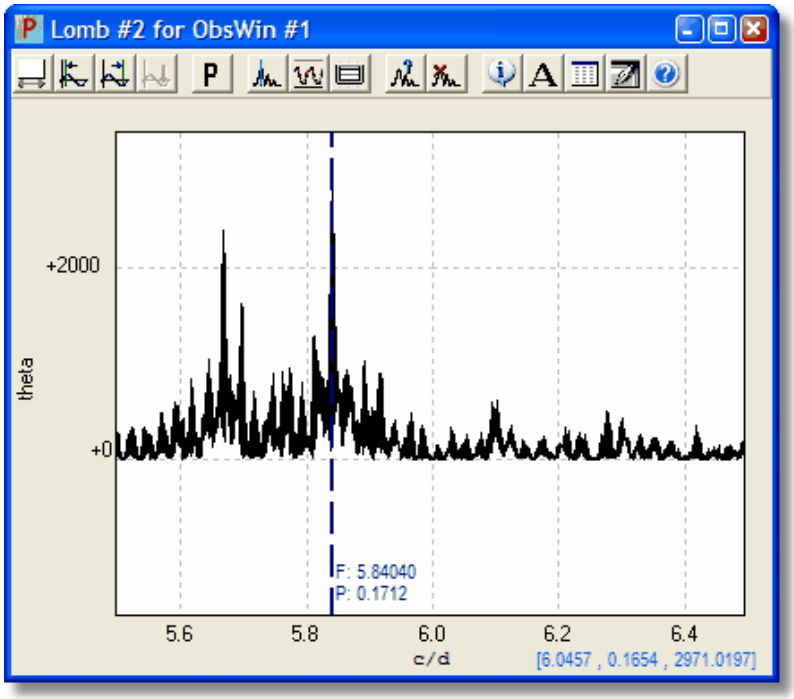


5. This creates a new Period Window (PerWin) with caption "*Lomb #2 for ObsWin #1*". Follow the instructions from Tutorial 1 to determine the new dominant period. You will find a value of 5.840 c/d, which is quite different from our initial value of 5.6690 c/d. The initial dominant period is still visible in the PerWin, but has become less pronounced. Note that the value of 5.840 c/d is in very good agreement with the published value of 5.839 c/d. The fact that both the 5.669 c/d and 5.840 c/d signals are dominantly present in the Period Window is a first indication that V350 Peg might be a multi-periodic Delta Scuti star.



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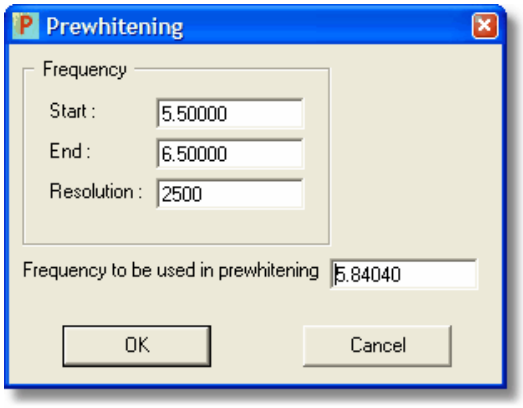
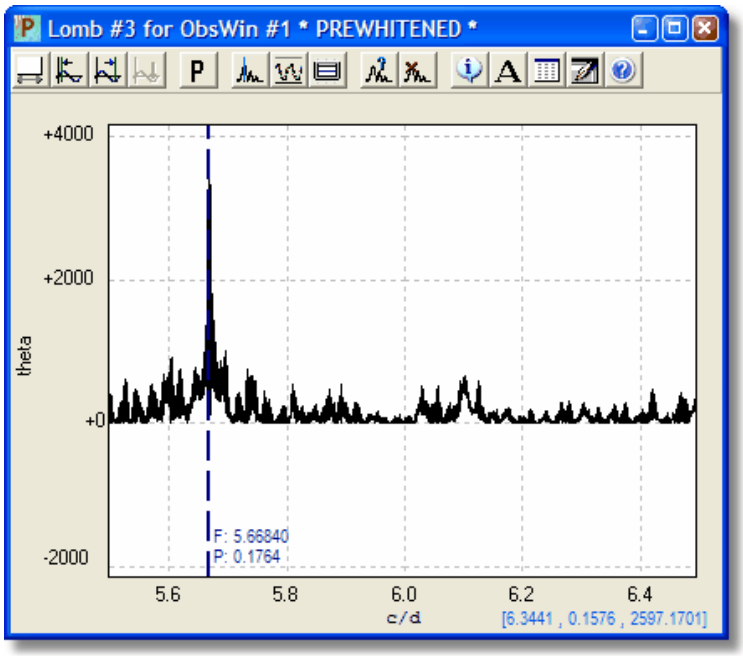
6.6 Finding multiple periods using prewhitening

The Period Window "*Lomb #2*" shows a dominant signal at 5.840 c/d. We will subtract this signal from the observations, leaving the so called residuals. We will then start a new period analysis on the residuals. This process is called prewhitening. If a dominant signal appears in the residuals, then the variable most likely is a multi-periodic system.

1. Select **Prewhitening** in the **Period Analysis** menu of PerWin "Lomb #2" (or click on the Prewhitening button in the PerWin Toolbar) to display the **Prewhitening** dialog box.



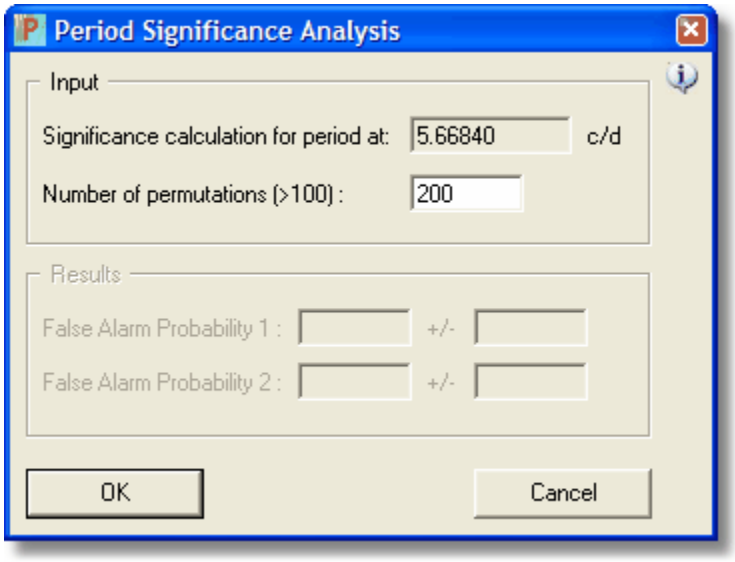
2. Accept the default values and click **OK** to start the Prewhitening calculation using a frequency of 5.84040 c/d. This creates a Period Window (PerWin) with caption "*Lomb #3 for ObsWin #1 *PREWHITENED**". We have removed the signal at 5.840 c/d. Follow the instructions from Tutorial 1 to again determine the dominant period. You will find a value of 5.668 c/d. We now have good reasons to assume that V350 Peg is a multi-periodic Delta Scuti star with signals at 5.668 c/d and 5.840 c/d.



6.7 Period Significance and Period Error

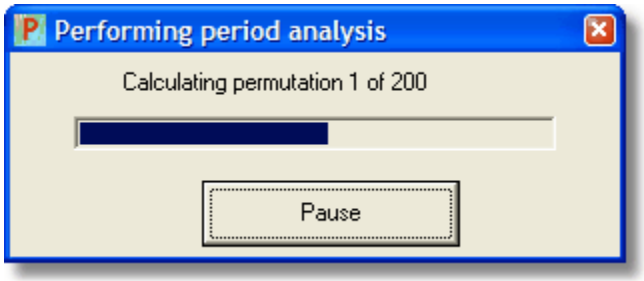
Before concluding our period analysis, we need to determine how significant the signals are, and what the uncertainty (or error) is on their frequency values. Use steps 1 - 4 to calculate the period significance, and steps 5 - 6 to determine the period error.

1. Select **Period Significance Analysis** in the **Period Analysis** menu of PerWin "*Lomb #3*" (or click on in the PerWin Toolbar) to display the **Period Significance Analysis** dialog box.



2. *Peranso* uses a *Fisher Randomization Test* to calculate 2 complimentary **False Alarm Probabilities** (FAP) for determining the significance of a signal. The section Period Significance Analysis provides full details. The **Period Significance Analysis** dialog box has an **Input** frame and a **Results** frame. Click the **OK** button to calculate the significance of the signal at 5.6684 c/d, using a set of 200 permutations.

3. *Peranso* starts calculating period diagrams for each permutation. Evidently, this is a very CPU-intensive command, that may take several hours to complete. The progress of the calculations is indicated by a dialog box with a **Pause** button.



4. Click the **Pause** button to interrupt the calculations. This again brings up the **Period Significance Analysis** dialog box. It shows the intermediate FAP values and their 1-sigma error values (if any). Click the **Info** icon to display a pop-up help window with some background information on the Significance calculations.

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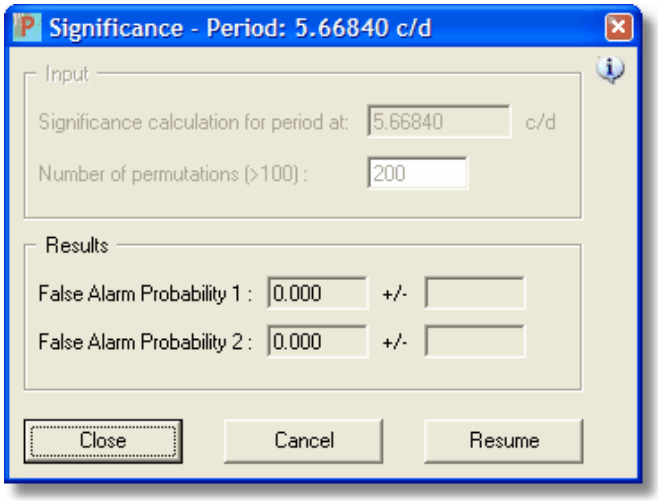
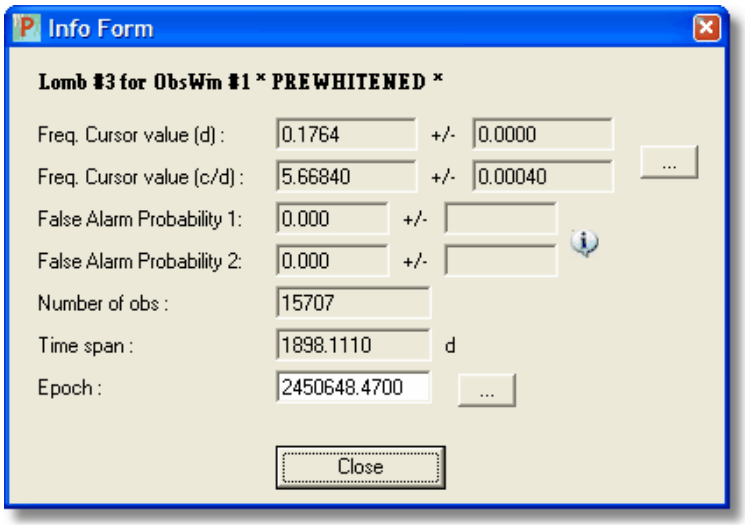
⇨ Click **Resume** to continue from the point were you interrupted (paused) the calculations.
⇨ Click **Close** to quit the calculation and to accept the current FAP values. They are memorized in the PerWin and will be displayed each time you click on the **Info** button in the PerWin Toolbar.
⇨ Click **Cancel** to terminate the significance calculations and to discard intermediate FAP values.

If you resume the calculations, you will find that the signal at 5.668 c/d has a very low FAP (around 0.0), hence a high significance. Likewise, the signal at 5.840 c/d has a very high significance too.



Determining the Period Error

5. Click on in the PerWin Toolbar to display the **Info** dialog box. It shows the Time and Frequency value of the dominant period, along with an estimate of the period uncertainty (period error), indicated by the values behind the **+/-** symbol. We thus find that the signal at 5.66840 c/d has a period error of 0.00040.



6. Click on the small button labeled "**...**", next to the period error fields, to display the **Mean Noise**

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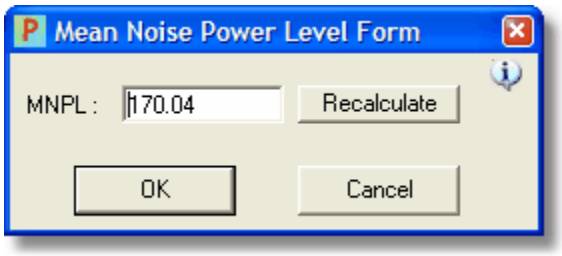
Power Level dialog box. *Peranso* determines the minimum error of the dominant period P, by calculating a 1-sigma confidence interval on P, using a method described by *Schwarzenberg-Czerny* (1). That method requires the so called **Mean Noise Power Level** (MNPL) in the vicinity of P. *Peranso* calculates an approximated MNPL value, or allows the user to estimate the MNPL. The human eye appears to be a good MNPL estimator : simply look at the PerWin and estimate the mean level of the power spectrum (or equivalent) around P, ignoring all strong lines and their aliases.

Accept the default MNPL value proposed by *Peranso* and click **OK** to close the form. If you enter a different MNPL value in the **Mean Noise Power Level Form** and click **OK**, then the period error values in the **Info** form are recalculated to reflect the new MNPL value. Use the **Recalculate** button to let *Peranso* determine the MNPL value.



7. Finally, create a Spectral Window (explained in Tutorial 1) to confirm that the periods found in the previous steps are not an artifact of the observing rate.

Conclusions

Analyzing 16191 observations of the Delta Scuti star V350 Peg, obtained between 1997 and 2002, spread over 50 sets of observations, we have ‘re-discovered’ the multi-periodic character of this variable star.

Using the Lomb-Scargle period analysis method, we found a first period at 5.668 c/d and a second one at 5.840 c/d. On the basis of a Fisher Randomization method, we found very low False Alarm Probability levels, indicating that both periods are significant.

Using the Schwarzenberg-Czerny method, calculating a 1-sigma confidence interval on both periods, we found period errors of 0.00040.

(1) Schwarzenberg-Czerny, A., 1991, Mon. Not. R. astr. Soc., 253, 198-206.

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Part VII

7 Tutorial 3 : Finding Multiple Periods using CLEANEST

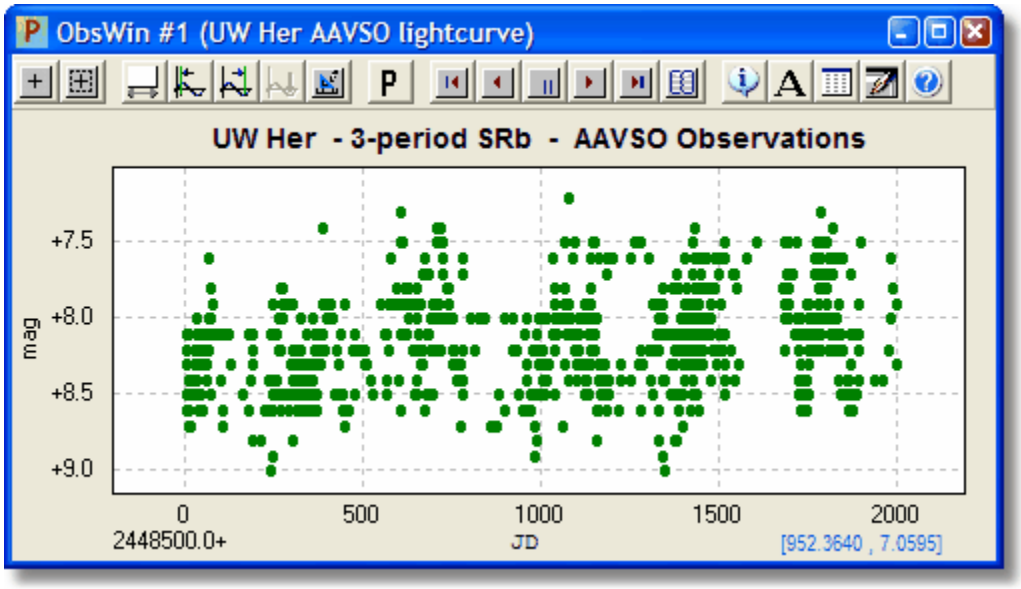
This tutorial explains the usage of the **CLEANest** method, to iteratively extract the multi-periodic signals from the AAVSO light curve of *UW Her*, a semi-regular SRb variable star (1).

The observations in this tutorial have been extracted from the *AAVSO International Database* (2).

(1) Kiss, L.L., et al., Astron. Astrophys., 346, 542-555,1999
(2) We acknowledge with thanks the variable star observations from the **AAVSO International Database** contributed by observers worldwide, and used in this research.

7.1 Determining the SLICK spectrum

1. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*UW Her AAVSO lightcurve*" and click the **Open** button. This loads the contents of the file and creates an Observations Window (ObsWin) with caption "*UW Her AAVSO lightcurve*", showing 773 observations obtained between JD 2448500 and JD 2450499.



2. Click on the **Period Determination** button in the ObsWin Toolbar to display the **Period Determination** dialog box. Select **Freq** as Unit , enter 0.0007 as **start** frequency, 0.015 as **end** and 1500 as **resolution**. Select **CLEANest (Foster)** as method and then click the **OK** button. This creates a Period Window (PerWin) with caption "CLEANest *#1 for ObsWin #1*", showing a complex DCDFT spectrum with peaks near 0.0010 c/d and 0.0093 c/d.

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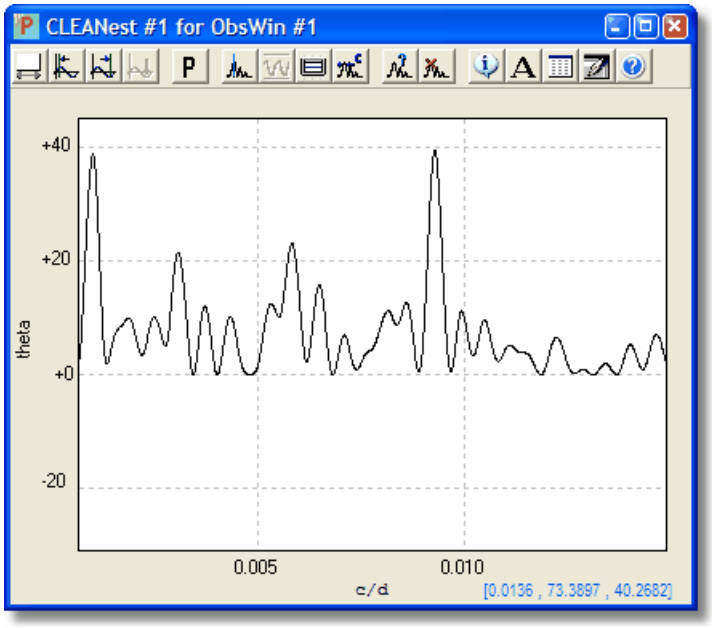
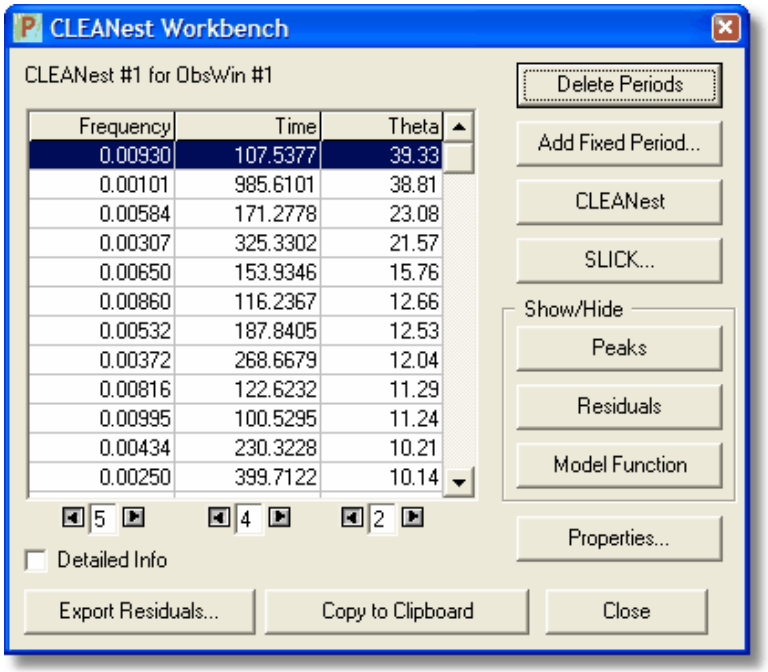


3. Select **CLEANest Workbench** in the **Period Analysis** menu (or click on in the PerWin Toolbar) to display the **CLEANest Workbench**. It consists of a tabular data grid, that we further refer to as the Peaks Table, and a series of command buttons. The Peaks Table is similar to the Prominent Periods Table : whenever *Peranso* finds a frequency (or period) whose power level is higher than its neighbors (i.e., when it finds a 'peak'), *Peranso* checks the power level to determine if this peak is one of the 20 best found so far. If so, it saves the relevant information (frequency, period, power level, etc.) in the Peaks Table.

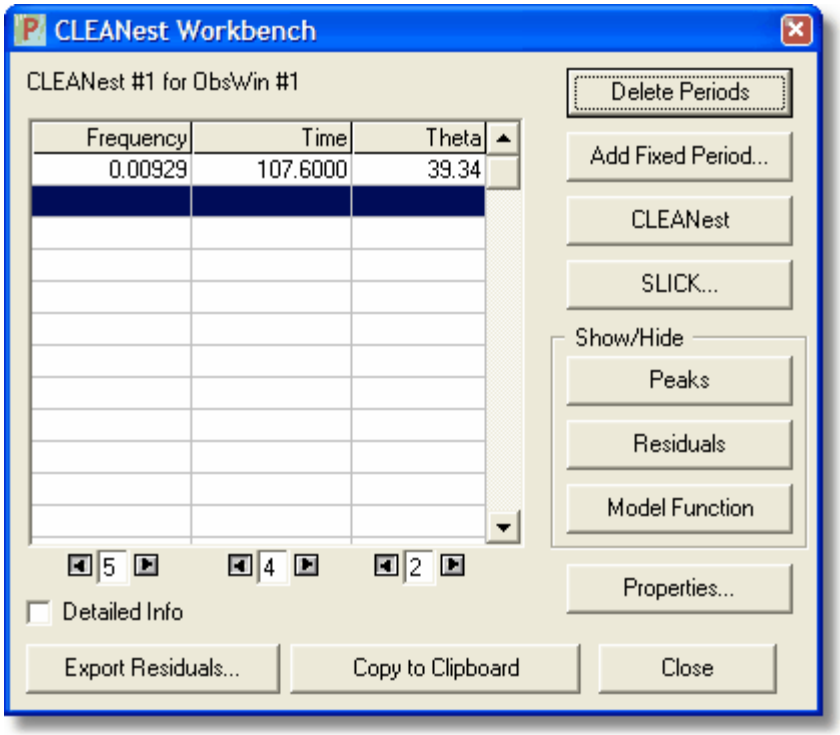


4. The strongest peak of Step 2 appears at a period of 107.54d (0.00930 c/d) with a power (theta) value of 39.33. Since we are not yet interested in other periods, we delete all entries of the Peaks

Table, except for the first one. This is done by selecting the corresponding rows in the table and by then pushing the **Delete Periods** button.

Whenever one runs a Fourier analysis, it is possible that the peak signal may not be the precise frequency actually detected in the data set, because the sampled frequencies tested might be offset slightly from the true signals. We use the **CLEANest** button to perform this refinement. First select the remaining entry in the Peaks Table, and then press the **CLEANest** button. View the table. You should see that the first period has been displaced in the table, and that a new entry appears above it, with period 107.60d and a power of 39.34.

Delete the old (second) entry from the Peaks Table, using the **Delete Periods** button.



5. We will now create the CLEANest(1) spectrum, or more precisely SLICK(1) spectrum. This is done by subtracting the peak from the time series data, and by doing a Fourier transform of the residual spectrum. This operation is accomplished with the **SLICK** button. First select the strongest peak (period 107.60 d) from the Peaks Table, and then click the **SLICK** button. Accept the proposed parameters for the period calculations.

   Once the Fourier transform of the residual spectrum has been completed, the Peaks Table is automatically updated to indicate the new peaks of the residual spectrum. The entry with period 107.60d evidently is maintained.

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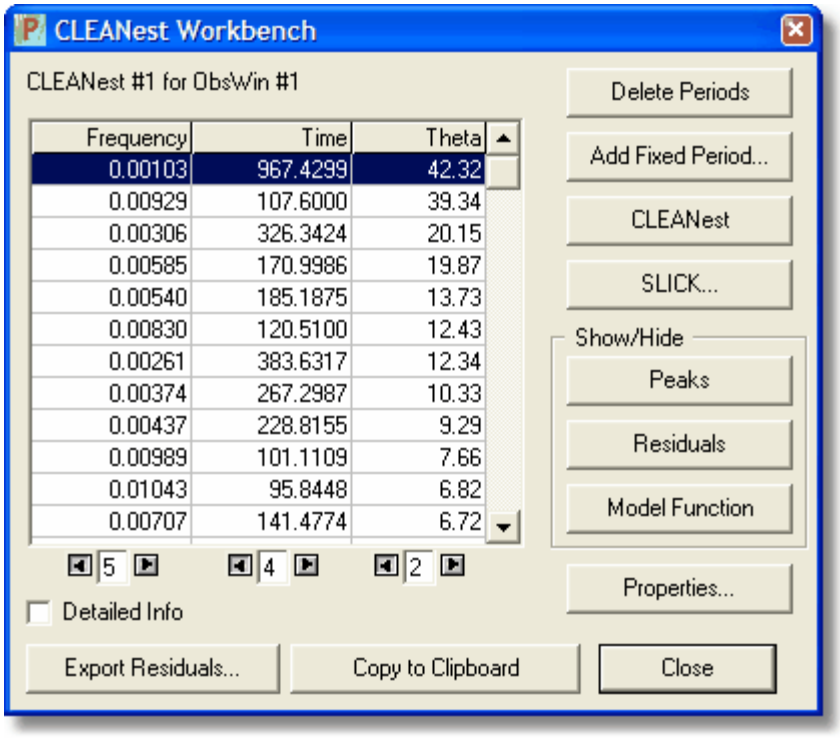
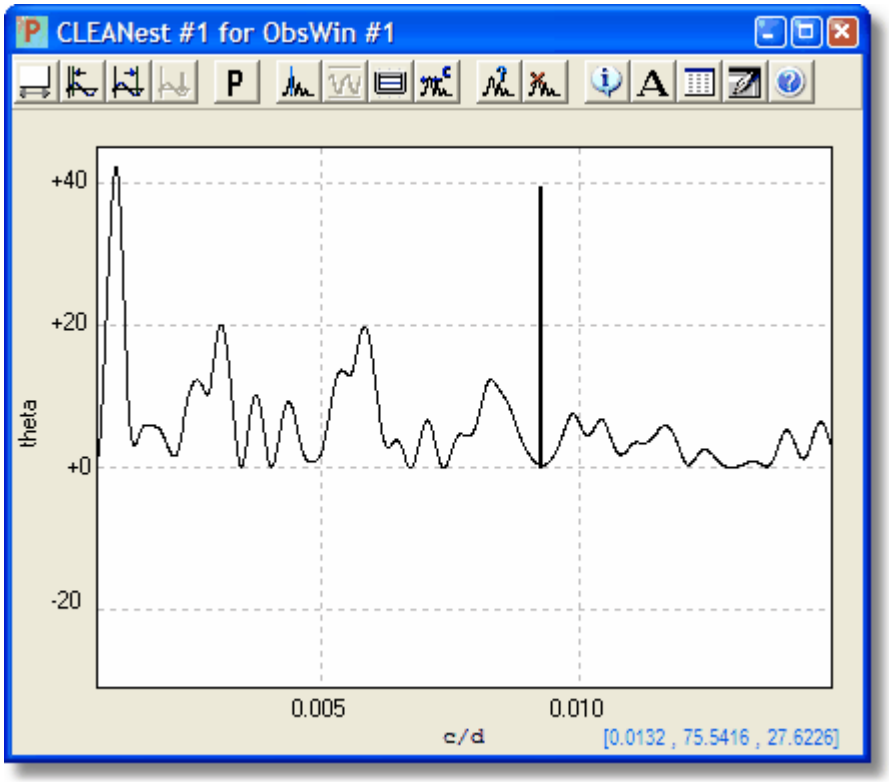
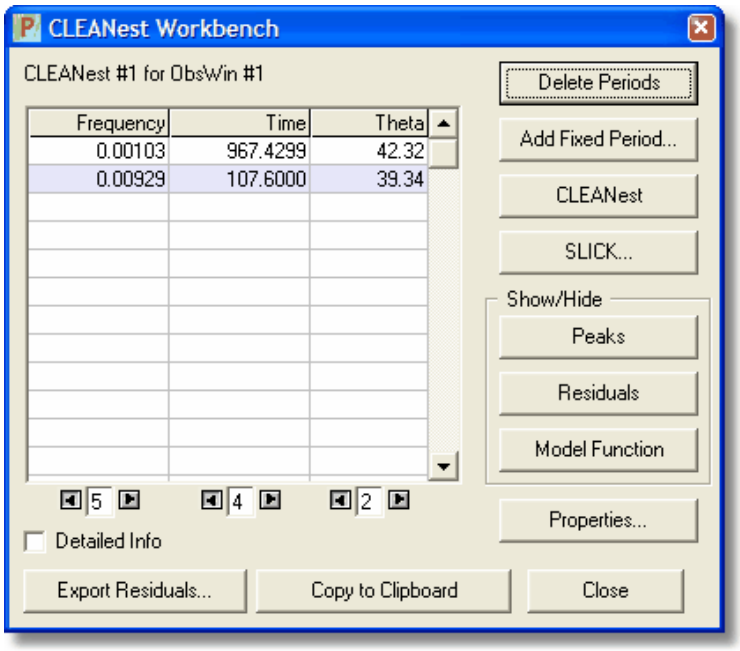


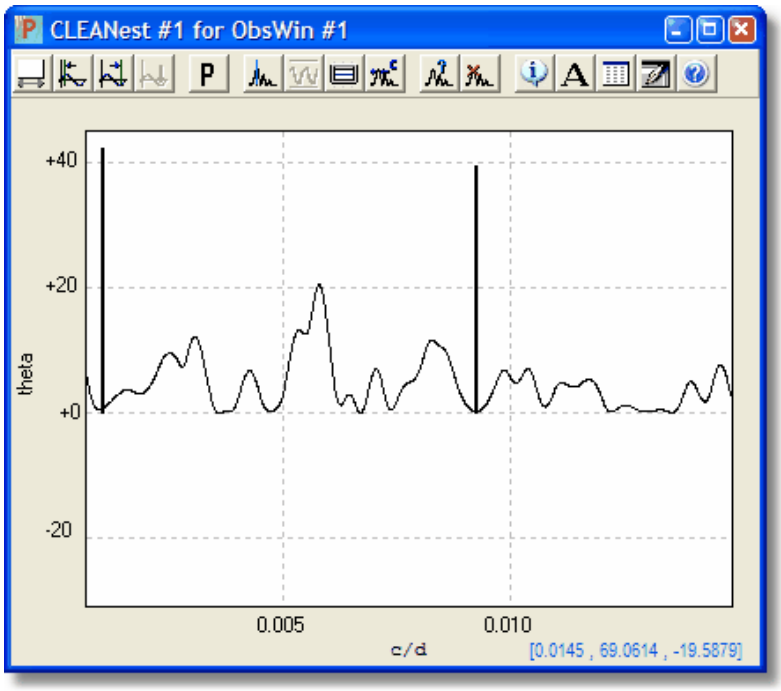
6. Select that entry and click the **Show/Hide Peaks** button to draw the discrete spectrum peak at a period of 107.60d. The corresponding entry in the Peaks Table is highlighted in color lavender, to indicate the existence of a discrete spectrum peak.



7. We continue with the calculation of the SLICK(2) spectrum. This is done by subtracting the two best peaks from the time-series data, and by doing a Fourier transform of the residual spectrum. This operation is accomplished by removing all peaks from the Peaks Table, except for the 2 top ones. Select those 2 peaks (the one at period 967.43d, and the one at 107.60d) in the Peaks Table and click the **SLICK** button. Again, accept the default period determination parameters.



8. Once the Fourier transform of the residual spectrum has been completed, select the peak at 967.43d in the Peaks Table and press the **Show/Hide Peaks** button to create the SLICK(2) spectrum.



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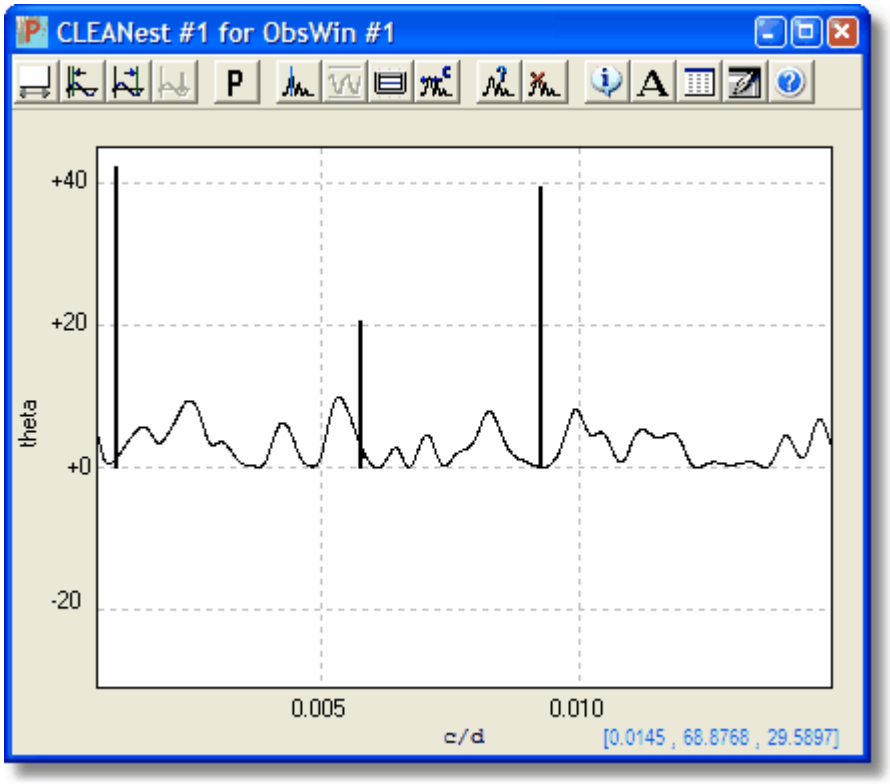
9. Looking at the residual spectrum of SLICK(2), it is clear that more statistically significant peaks may still be present, so we continue our calculations, this time eliminating all but the three most dominant peaks for the SLICK calculation. The SLICK(3) spectrum is determined, yielding a third peak at 172.40d with a power level of 20.49.



10. The residual spectrum of SLICK(3) no longer shows peaks above a power level of 10 (half of the power level of the third peak), so we stop our multi-period scan at this stage, and delete all periods in the Peaks Table, expect for the 3 top entries.Select the '**Detailed Info**' option to expand the CLEANest Workbench dialog box. A number of new columns appear : amplitude and phase of the peaks, and error values for frequency, period and amplitude.

    To increase the number of decimal places used in the columns, click the left-arrow or right-arrow buttons of the precision indicators, or directly enter the precision value in the corresponding text box.

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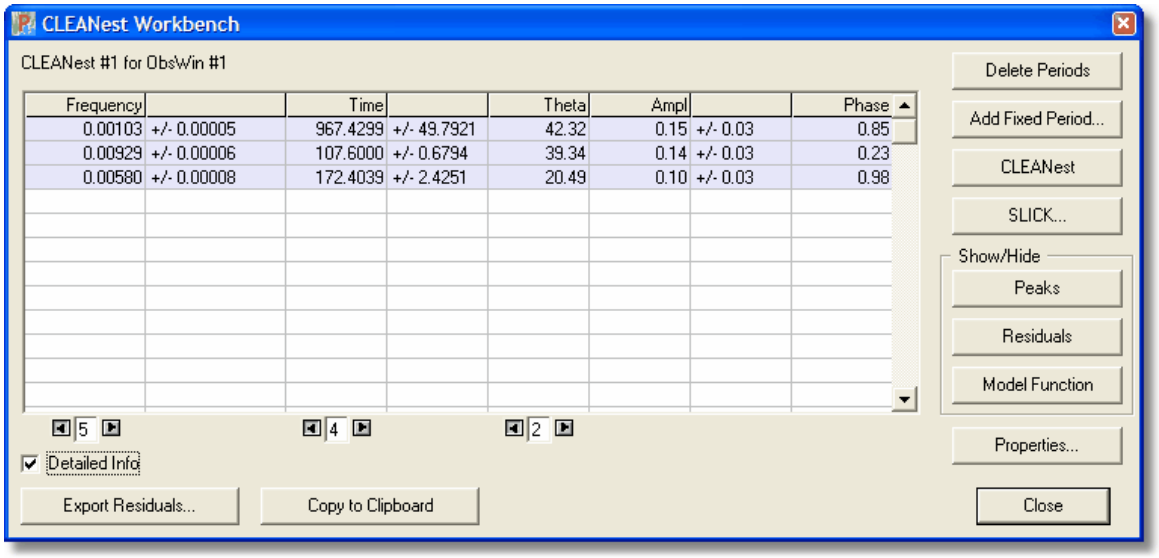

11. Finally, create a Spectral Window (explained in Tutorial 1) to confirm that the periods found in this step are not an artifact of the observing rate.

We conclude that *UW Her* is a tri-period system with periods :

P0 : 967.4 +/- 49.8 d
P1 : 107.6 +/- 0.7 d
P2 : 172.4 +/- 2.4 d

Literature (1) mentions values of 1000 +/- 10 d, 107 +/- 1 d and 172 +/- 1 d, which is in very good agreement with our analysis.

(1) Kiss, L.L., et al., Astron. Astrophys., 346, 542-555,1999

7.2 Working with the Model Function and Residuals

After determining the best periods, you may want to see exactly how they fit the observations. This is done by drawing a Model Function on top of the data of the Observations Window.

1. Select the 3 periods in the Peaks Table and click the **Model Function** button to draw the Model Function in the Observations Window. It appears in dark gray, superimposed on the observations. We call such a graphical superposition an Overlay. The Model Function quite well represents the observed *UW Her* data. Use the **Properties** button of the CLEANest Workbench to select a different color or line width for the Model Function.

   When saving your analysis results to a *Peranso* file, the Model Function will be stored as well.

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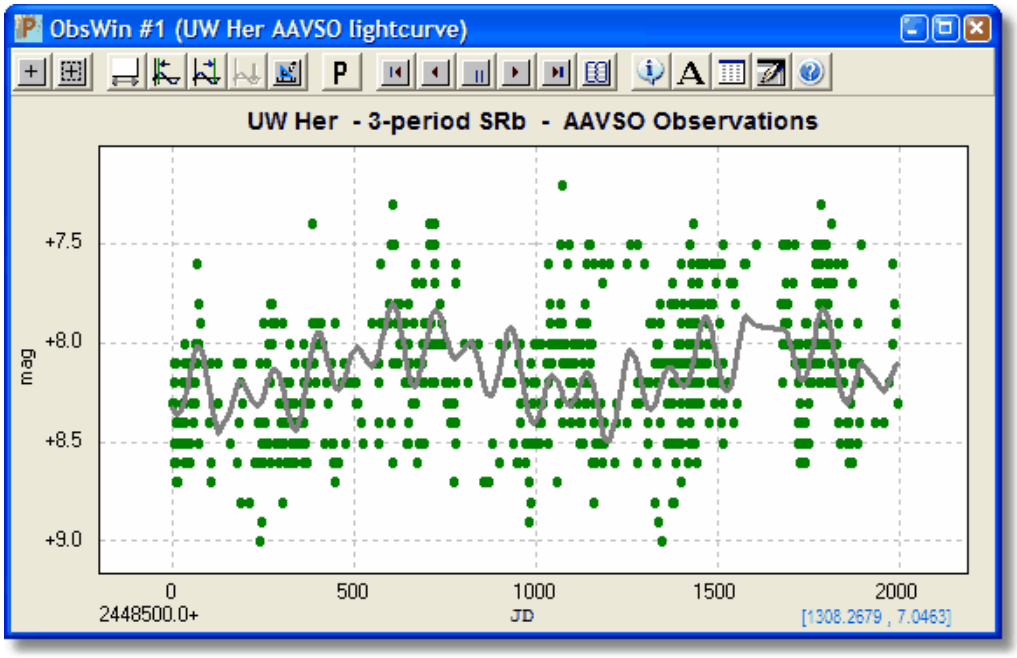
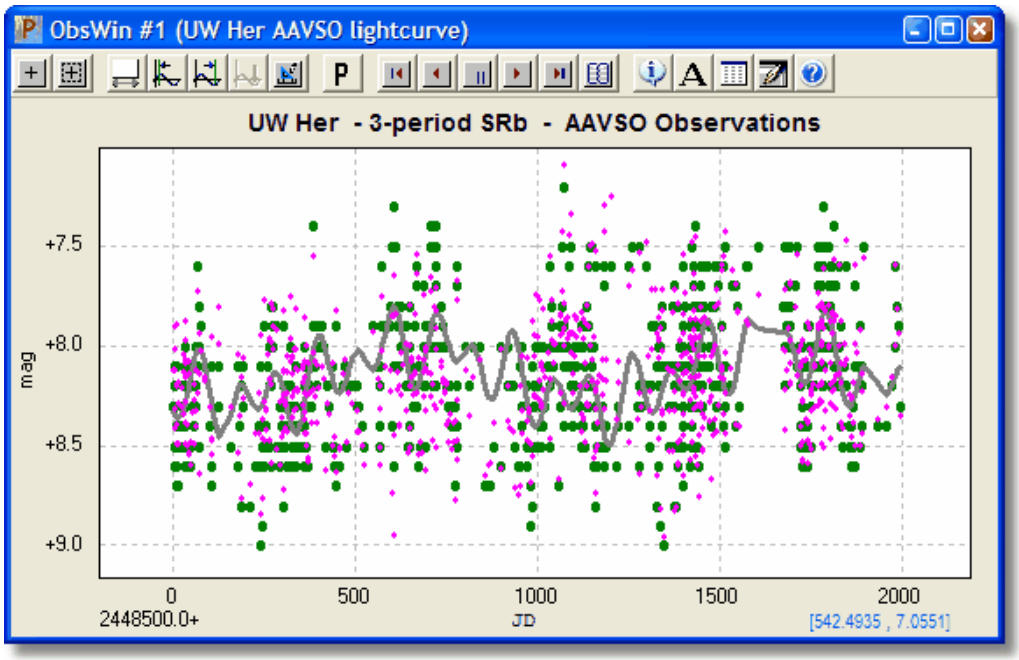


2. A final step in analyzing the quality of the identified periods is by calculating the residual values (short, Residuals), that result from subtracting the Model Function from the observations.

   Select the 3 periods of interest in the Peaks Table, and click the **Residuals** button to visualize the Residuals in the Observations Window. They appear in color fuchsia, as an Overlay. Use the **Properties** button of the CLEANest Workbench to select a different color or dot size for the Residuals.

   When saving your analysis results to a *Peranso* file, the Residuals will be stored as well.



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3. The **Peaks**, **Residuals** and **Model Function** buttons of the CLEANest Workbench act as toggle buttons.

   Export Residuals : this command is used to export the residual data to file, instead of plotting them as an Overlay. First select the peaks of interest in the Peaks Table. The Export Residuals command is a valuable step to search for further periodicities in the residuals, using the variety of methods that *Peranso* offers.

   Add Fixed Period : this command is used to add a (user-defined) fixed period to the Peaks Table. This option should only be used if you know that a period exists in the data, which is stable and accurately determined (e.g., if you know the period of a binary to very high precision, but have not yet identified it with the Period Determination command, enter it here).

   Copy To Clipboard : this command is used to copy the contents of the Peaks Table to the Microsoft Windows clipboard. First select the peaks of interest.

   Close : this command is used to close the CLEANest Workbench. Its contents are always saved to file, whenever you execute a *Peranso* save operation.

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Part VIII

8 Tutorial 4 : Using the EEBLS Method for Exoplanet Transit Searches

Peranso supports the EEBLS (Edge Enhanced Box-fitting Least Squares) period analysis method. Box-fitting Least Squares (BLS) algorithms (1) are particularly effective to analyze stellar photometric time series in search for periodic transits by *exoplanets*. It searches for signals characterized by a periodic alternation between two discrete levels, with much less time spent at the lower level. EEBLS is an extension to BLS, that takes into account edge effects during exoplanet transits, as suggested by *Dr. Peter McCullough* (STScI).

Peranso allows calculating and visualizing the EEBLS frequency spectrum, folding of the time series over the most dominant EEBLS period, calculating the epoch of mid-transit events, the transit depth and duration, etc. In addition, *Peranso* graphically displays the fit obtained by the EEBLS method.

This tutorial describes the usage of EEBLS in *Peranso*.

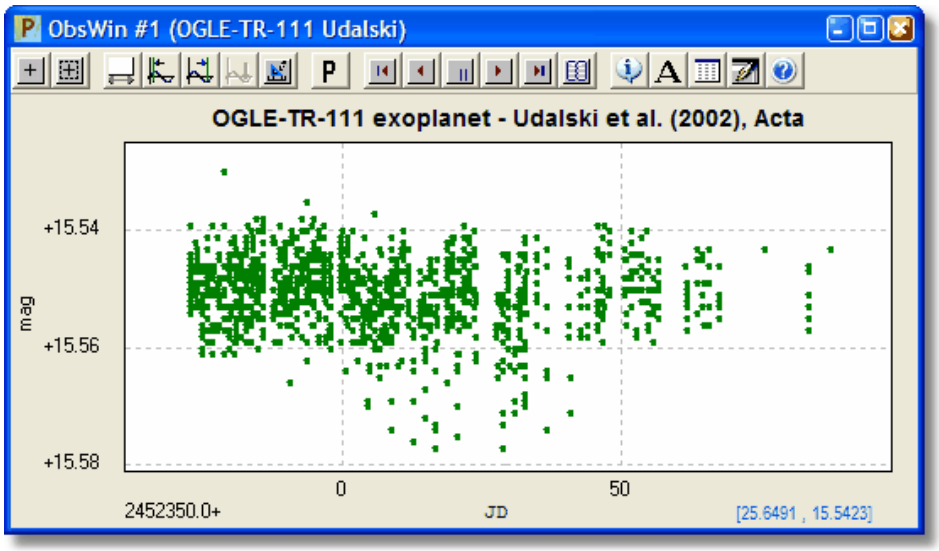
(1) Kovacs G., Zucker S., Mazeh T., *A box-fitting algorithm in the search for periodic transits*, A&A, 2002.

8.1 Importing exoplanet time series in Peranso

In this tutorial, we use time series observations of exoplanet *OGLE-TR-111*, that are publicly available at *The Optical Gravitational Lensing Experiment* (1) OGLE website (http://sirius.astrouw.edu.pl/~ogle/ogle3/transits/OGLE-TR-111.html).

1. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*OGLE-TR-111 Udalski"* and click the **Open** button.

2. This loads the contents of the file and creates an Observations Window (ObsWin) with caption "*OGLE-TR-111 Udalski*"



(1) Udalski et al., Acta Astron. 52, 317, 2002.

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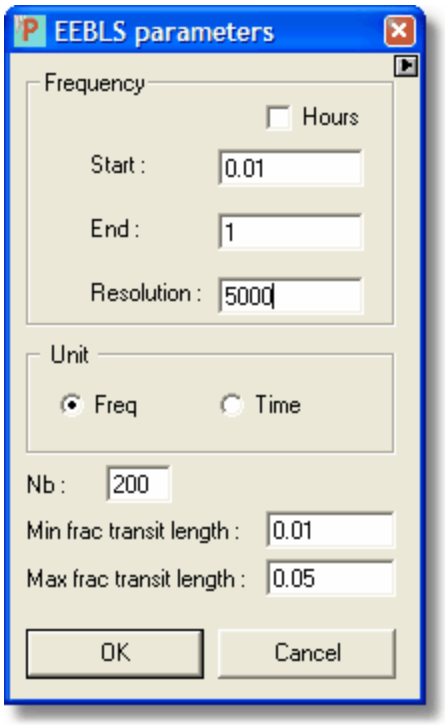
8.2 EEBLS period search

1. Select **EEBLS (exoplanet transits)** in the **Period Analysis** menu to display the **EEBLS Parameters** dialog box.



2. Enter **start** and **end** values for the EEBLS period analysis, as well as the **resolution** to be used. Select whether you want the period calculations to happen in the **Time** or **Freq**uency domain. Then enter the number of bins **Nb** and the **minimum** resp. **maximum fractional transit length** to be used for the EEBLS calculation.

   The fractional transit length is assumed to be a small number (usually between 0.01 and 0.05) and denotes the time spent in the transit phase, relative to the total transit duration.

   Enter the values shown in the screen shot above. Click **OK** to start the EEBLS calculation. The EEBLS algorithm aims to find the best model with estimators for the transit period, depth and length, as well as the epoch of mid transit and the phase of ingress and egress.

3. This creates a Period Window (PerWin) with caption "*EEBLS #1 for ObsWin #1*", called the EEBLS spectrum. Follow the instructions from Tutorial 1 to determine the dominant period. You will find a value of 0.24899 c/d or 4.0163 d, which corresponds very well with literature value.

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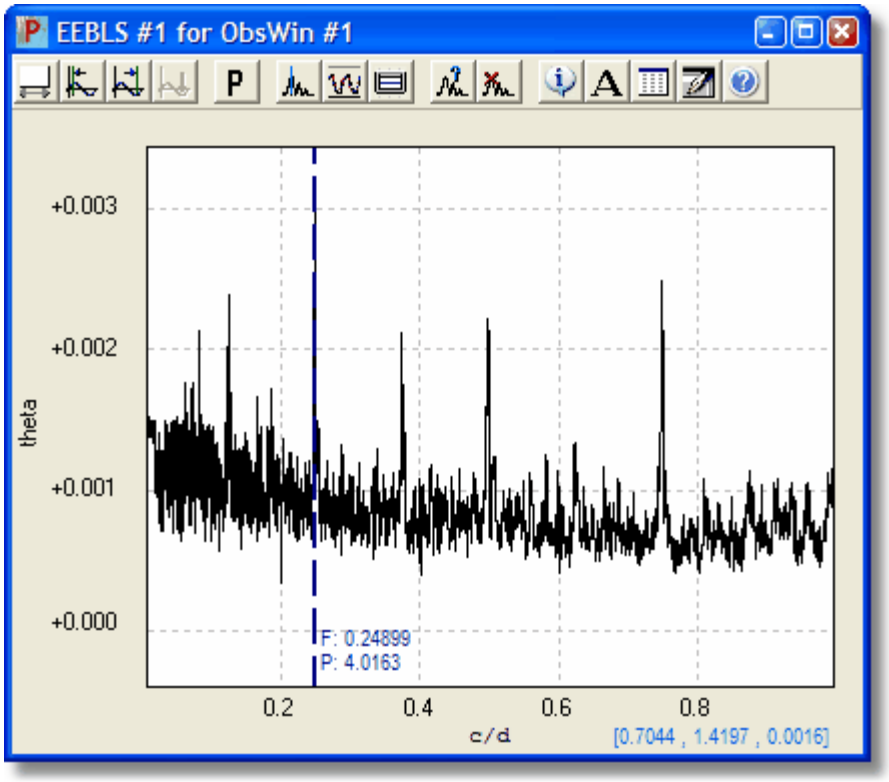

4. Select **Info** in the **Period Window** menu (or click on in the PerWin Toolbar) to display the **Info Form** dialog box. It contains the regular *Peranso* info fields, complemented with some EEBLS specific fields, that indicate :

   ⇨ the EEBLS period (in days),
   ⇨ the epoch of mid transit,
   ⇨ the transit depth,
   ⇨ the transit duration (in days),
   ⇨ the phase of ingress (transit start),
   ⇨ the phase of egress (transit end),
   ⇨ the value of the Tingley Exoplanet Diagnostic.

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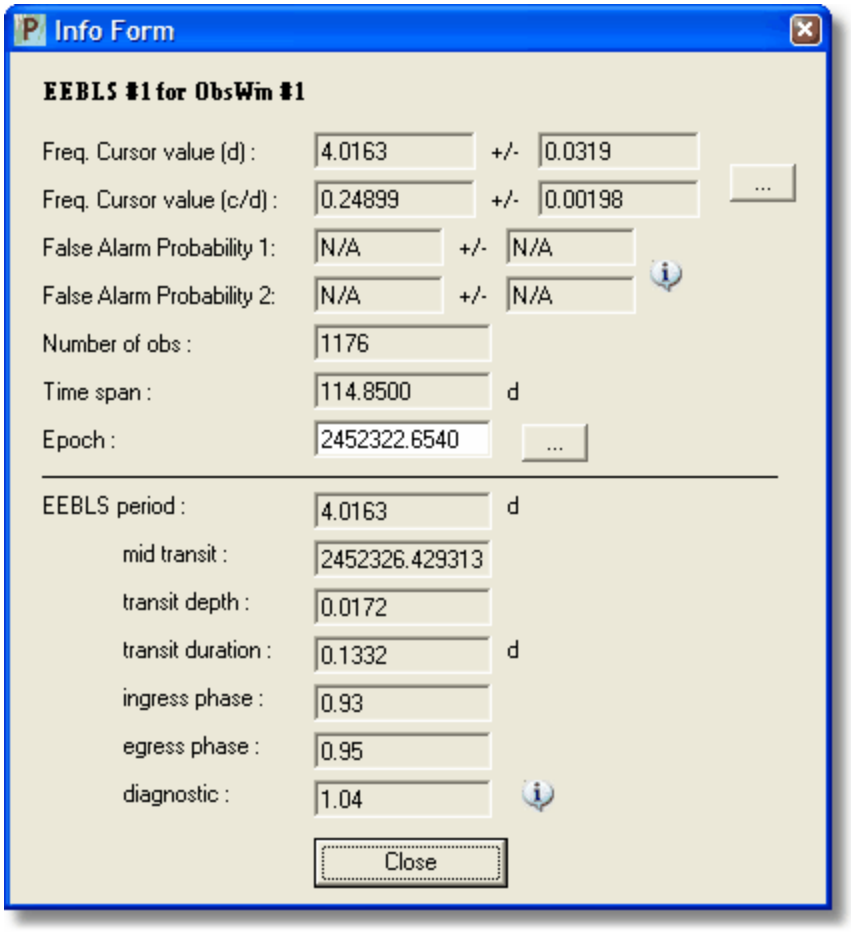
Info Form
EEBLS #1 for ObsWin #1
Freq. Cursor value (d) : 4.0163 +/- 0.0319
Freq. Cursor value (c/d) : 0.24899 +/- 0.00198
False Alarm Probability 1: N/A +/- N/A
False Alarm Probability 2: N/A +/- N/A
Number of obs : 1176
Time span : 114.8500 d
Epoch : 2452322.6540
EEBLS period : 4.0163 d
mid transit : 2452326.429313
transit depth : 0.0172
transit duration : 0.1332 d
ingress phase : 0.93
egress phase : 0.95
diagnostic : 1.04
Close

8.3 Displaying the graphical fit obtained by EEBLS

1. Select **PhaseWin at Frequency Cursor Value** in the **Period Analysis** menu (or click on in the PerWin Toolbar). This creates a Phase Window (PhaseWin) with caption "*PhaseWin - EEBLS #1 for ObsWin #1 - Freq 0.24899*", showing the result of folding the *OGLE-TR-111* time series data over the dominant period of 4.0163 d

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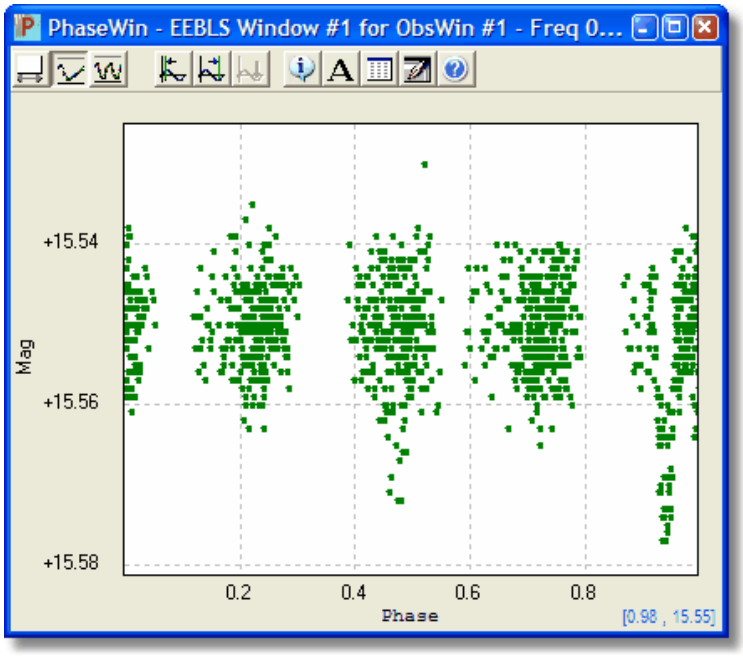
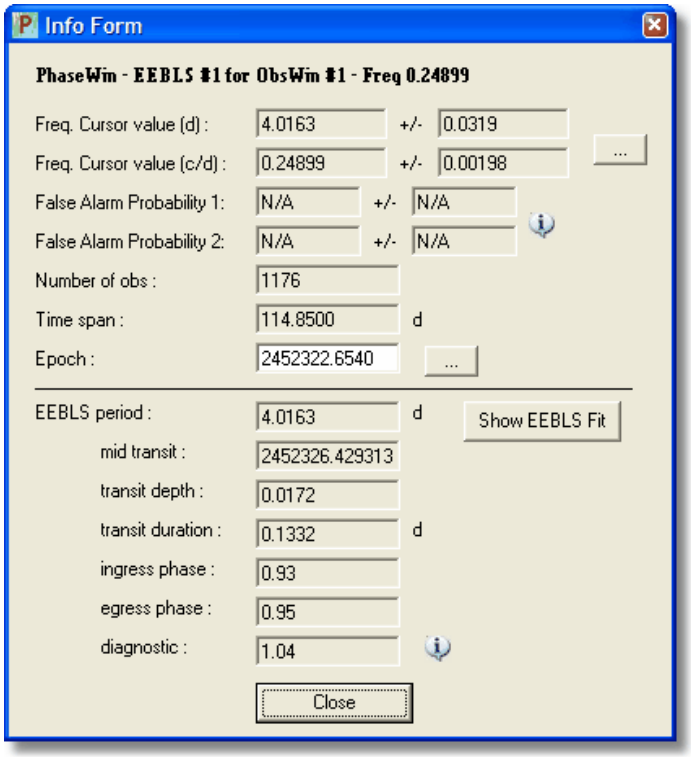


2. Select **Info** in the **Phase Window** menu (or click on in the PhaseWin Toolbar) to display the **Info Form** dialog box. It contains the same information as in the previous section, but now also has a button **Show EEBLS Fit**.


Info Form
PhaseWin - EEBLS #1 for ObsWin #1 - Freq 0.24899
Freq. Cursor value (d) : 4.0163 +/- 0.0319
Freq. Cursor value (c/d) : 0.24899 +/- 0.00198
False Alarm Probability 1: N/A +/- N/A
False Alarm Probability 2: N/A +/- N/A
Number of obs : 1176
Time span : 114.8500 d
Epoch : 2452322.6540
EEBLS period : 4.0163 d
Show EEBLS Fit
mid transit : 2452326.429313
transit depth : 0.0172
transit duration : 0.1332 d
ingress phase : 0.93
egress phase : 0.95
diagnostic : 1.04
Close

3. Click the **Show EEBLS Fit** button to graphically display the EEBLS fit in the PhaseWin (red line). The label of the Show EEBLS Fit button changes into **Hide EEBLS Fit**, allowing to toggle the visibility of the EEBLS fit.

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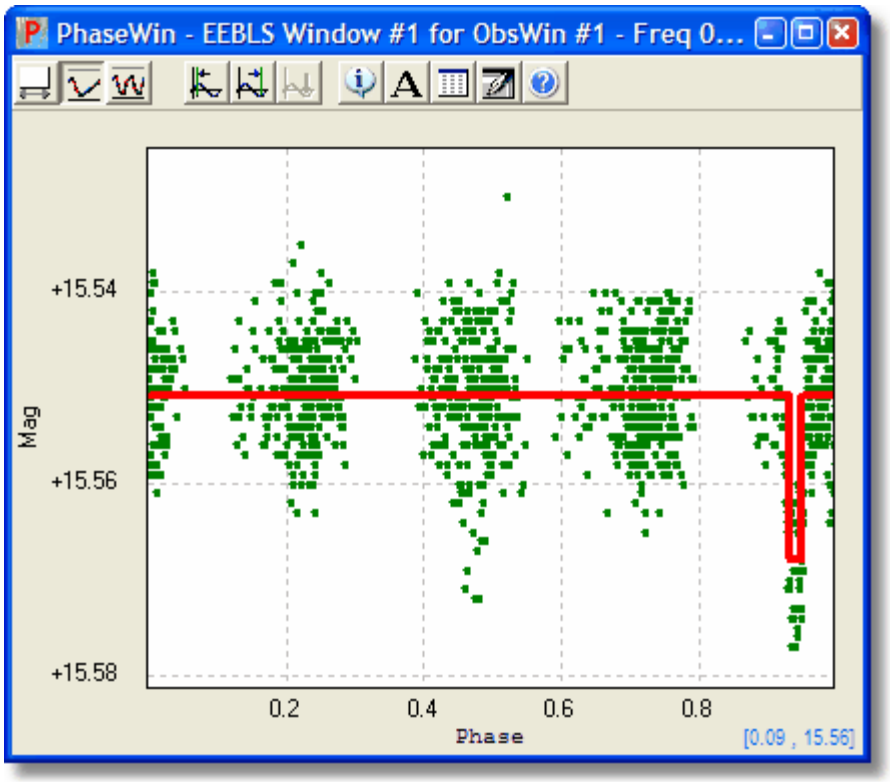
You can change the line color, thickness and style of the EEBLS fit using the Properties command of the PhaseWin. The **Cursors + Fit Curve** tab has a frame **Fit curve** with entries **Size**, **Style** and **Color** used to draw the EEBLS fit.



Part

9 Tutorial 5 : Using the EASolver Method for Eclipsing Algol-type (EA) Binaries

The public availability of photometric data resulting from automated star surveys, such as the *ASAS-3 All-Sky Automated Survey* (1), has made it possible to set up searches for new variable stars in the survey data. Some amateur astronomers have been particularly successful in discovering new variables by studying photometric data from ASAS-3, Hipparcos and other sources.

Patrick Wils (Vereniging voor Sterrenkunde, Belgium) has developed a novel period search method that operates on photometric survey data of eclipsing Algol-type (EA) binaries. These survey data regularly are characterized by a majority of observations showing the variable in normal light, and very sparse data showing the variable in an eclipsing state. A typical example of such a light curve is presented in the next section. It contains ASAS-3 observations of the variable star *NSV 10862*. Out of a total of 294 observations, only about 5 of them show the variable in faint state.

Peranso includes Patrick Wils' method to find the periodicities of EA binaries using photometric survey data, focusing only on the observations that correspond with a faint state of the variable. The method is called **EASolver**, and its usage is described in this brief tutorial. *EASolver* might be applicable to other type of variable star data analysis research as well.

In this tutorial, we use ASAS-3 observations of NSV 10862, kindly provided by *Sebastian Otero* (Centro de Estudios Astronómicos, Argentina).

(1) Pojmanski G., *The All Sky Automated Survey*, Acta Astronomica, 52, 397, 2002

9.1 Preparing the Observations Window for EASolver

1. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*NSV 10862 EA Solver*" and click the **Open** button.

2. This loads the contents of the file and creates an Observations Window (ObsWin) with caption "*NSV 10862 EA Solver*". It contains 2 observation sets (red and black colored). Most of the observations in the window show NSV 10862 in a bright state (out of eclipse), and only very few observations relate to a faint state (close to eclipse). EASolver will determine the period of NSV 10862, using only the faint-state observations.

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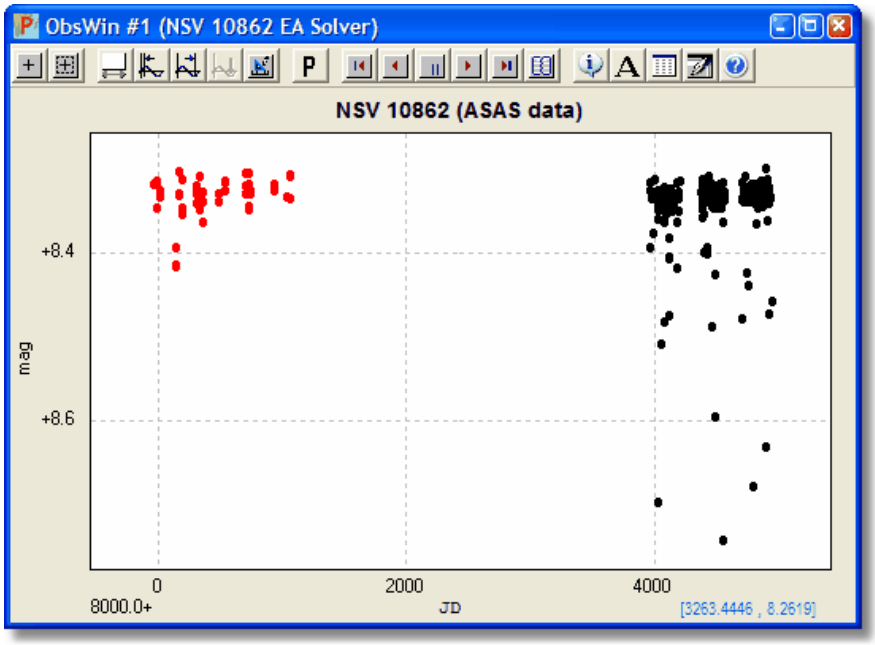
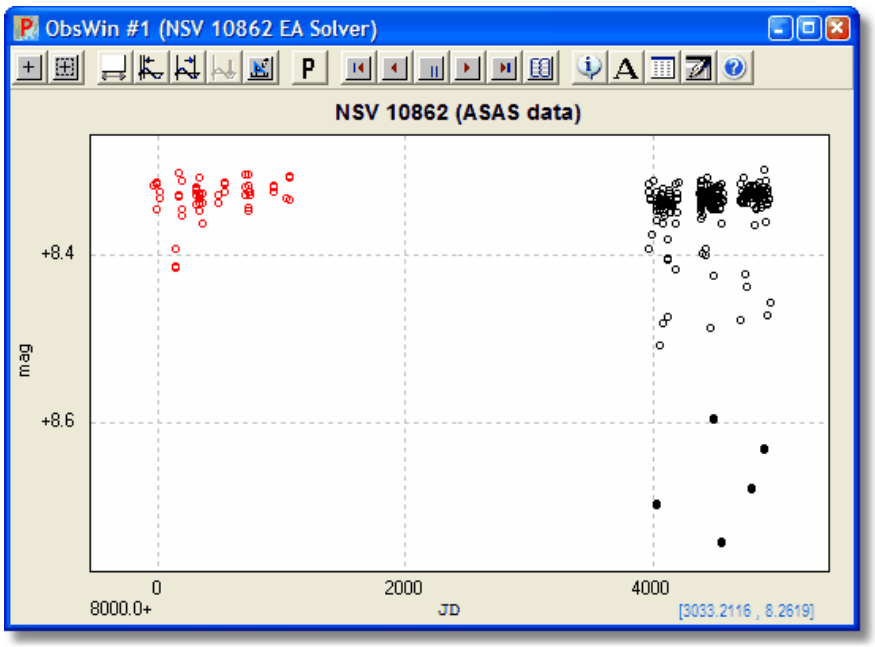


3. Tell *Peranso* to only work with faint-state observations, by deactivating all other observations. To deactivate a group of observations in an Observations Window, hold the Shift button on the keyboard, and meanwhile click and hold the left mouse button. A rubberband rectangle appears. Release the left mouse button when the rectangle contains the observations of interest. *Peranso* will toggle the Use state (active/deactive) of all observations within the rubberband rectangle.



Important remark : EASolver requires at least three observations showing the star in a faint state (close to or in eclipse). And you can only select one observation per faint state.

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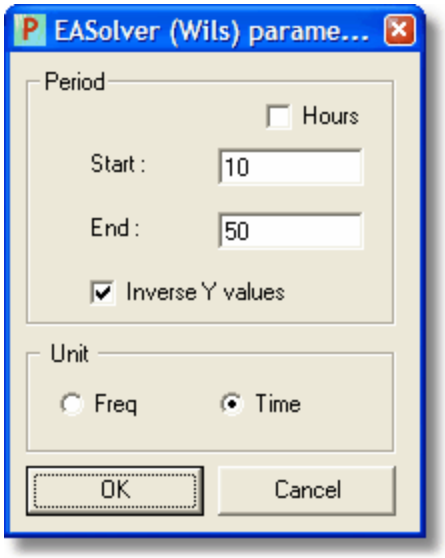
9.2 Running EASolver

1. Select **EASolver (Wils)** in the **Tools** menu to display the **EASolver (Wils) Parameters** dialog box. Enter **start** and **end** values for the EA Solver period analysis. Select whether you want the period calculations to happen in the **Time** or **Freq**uency domain. If you select **Inverse Y values**, the best periods in the Period Window will be shown as peaks. In the other case, best periods correspond with valleys in the Period Window.

   Enter the values shown in the screen shot below to run the analysis between 10 and 50 days, in the Time domain. Click **OK** to start the EA Solver calculation.



2. This creates a Period Window (PerWin) with caption "*EASolver #1 for ObsWin #1*". Follow the instructions from Tutorial 1 to determine the dominant period. You will find a value of 30.8101 d, which corresponds very well with literature value (1).

   In case the Period Window shows multiple peaks with the same height (as in our tutorial example), select the one with the highest period first for a more detailed analysis.

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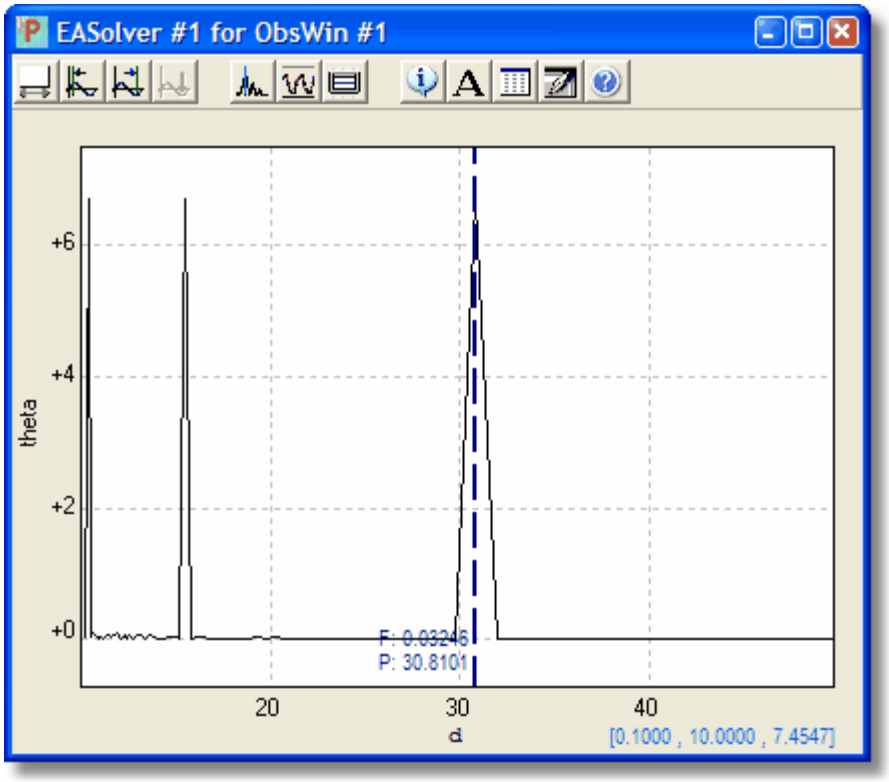
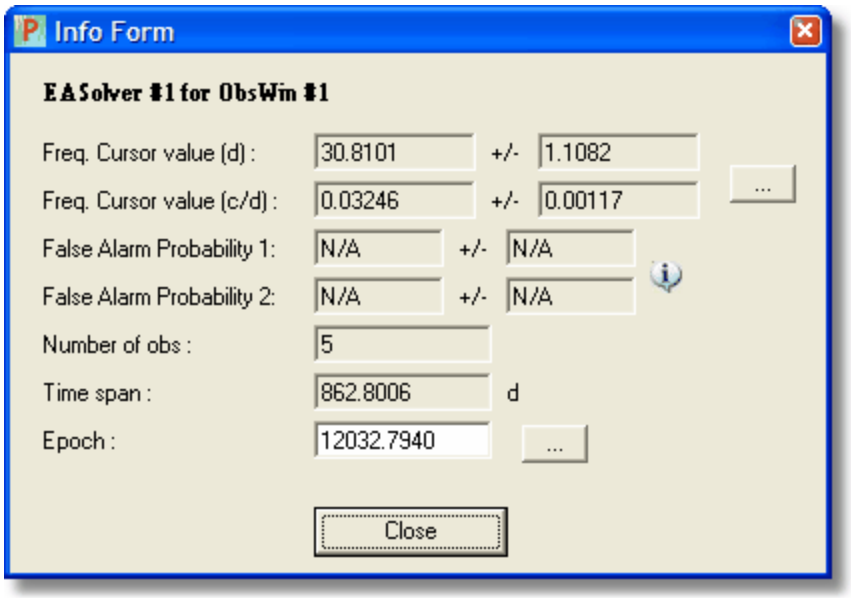


3. Select **Info** in the **Period Window** menu (or click on in the PerWin Toolbar) to display the **Info Form** dialog box. It contains the regular *Peranso* info fields.



(1) Otero S., Claus F., *New Elements for 80 Eclipsing Binaries II*, IBVS 5495, 15 Jan 2004

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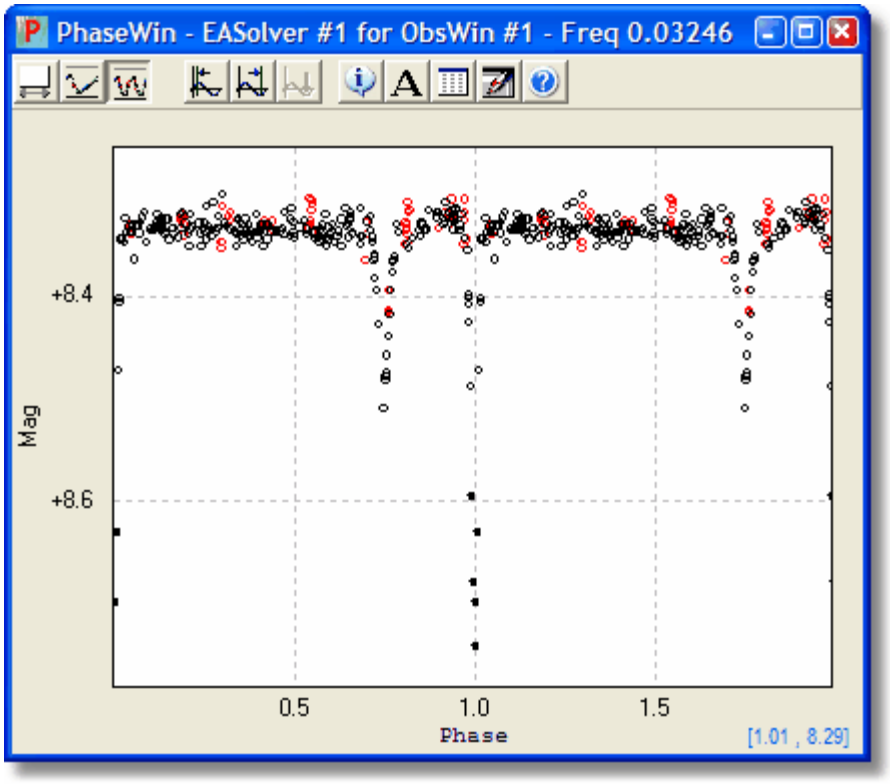
9.3 Analysing the Phase Window

1. Select **PhaseWin at Frequency Cursor Value** in the **Period Analysis** menu (or click on in the PerWin Toolbar). This creates a Phase Window (PhaseWin) with caption "*PhaseWin - EASolver #1 for ObsWin #1 - Freq 0.03246*", showing the result of folding the *NSV 10862* time series data over the dominant period of 30.8101 d.

   We clearly recognize the primary and secondary eclipses, and notice that NSV 10862 is an eccentric (rather than circular) binary.



2. Finally, inspect the Observations Window to ensure that no bright state observations occur at a predicted eclipse time. If that is the case, the true period of the system is probably longer, so select a longer period from the Prominent Periods Table.

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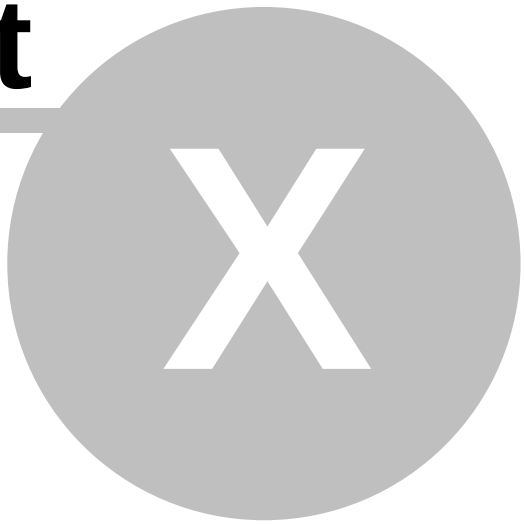
Part



10 Tutorial 6 : Using the FALC method on Asteroids and Variable Stars

This tutorial contains step-by-step instructions for finding the period of a light curve using the **FALC** (*Fourier Analysis of Light Curves*) method. FALC (Harris et. al., 1989) has been defined by Dr. Alan Harris (JPL), who is one of the most recognized leaders in asteroid research, and is a de facto standard for asteroid light curve period analysis.

Dr. Harris' method is fully integrated in *Peranso*, through the Period Determination dialog box, that features many other period analysis techniques. In addition, *Peranso* provides a FALC Workbench, that presents Dr. Harris' method in a convenient graphical user interface (GUI). This GUI is extremely useful for asteroid enthusiasts, and mimics FALCs original approach in a Windows environment. The *FALC Workbench* also provides sophisticated outputs, showing f.i. the uncertainty of the fitted curve. In addition, it allows to keep a period constant and increment harmonic orders, to determine the most significant fit order to work with.

Dr. Harris' method is very interesting too for variable star light curve analysis, as it effectively takes into account magnitude error values in the period determination. It currently is the only method in *Peranso* that uses the error bar (sigma) of magnitudes.

This tutorial contains two parts. Part 1 explains the usage of FALC based on the Period Analysis menu. Part 2 describes the FALC Workbench. You may use either method to do your FALC period analysis.

In this tutorial, we use observations of asteroid *390 Alma* by Robert D. Stephens (USA), retrieved from the Minor Planet Observer website (http://www.minorplanetobserver.com/adu/ADU_search.htm). In addition, we use observations of asteroid *45 Eugenia*, provided by Dr. Harris (JPL).

10.1 Part 1. Using the FALC method from the Period Analysis menu

10.1.1 Preparing the Observations Window for FALC

1. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*390 Alma FALC*" and click the **Open** button.

2. This loads the contents of the file and creates an Observations Window (ObsWin) with caption " *390 Alma FALC*". It contains 2 Observation Sets (blue and red colored). Each observation has an associated magnitude error (MagError) value. Magnitude error values are taken into account when performing a period analysis calculation using the FALC method.

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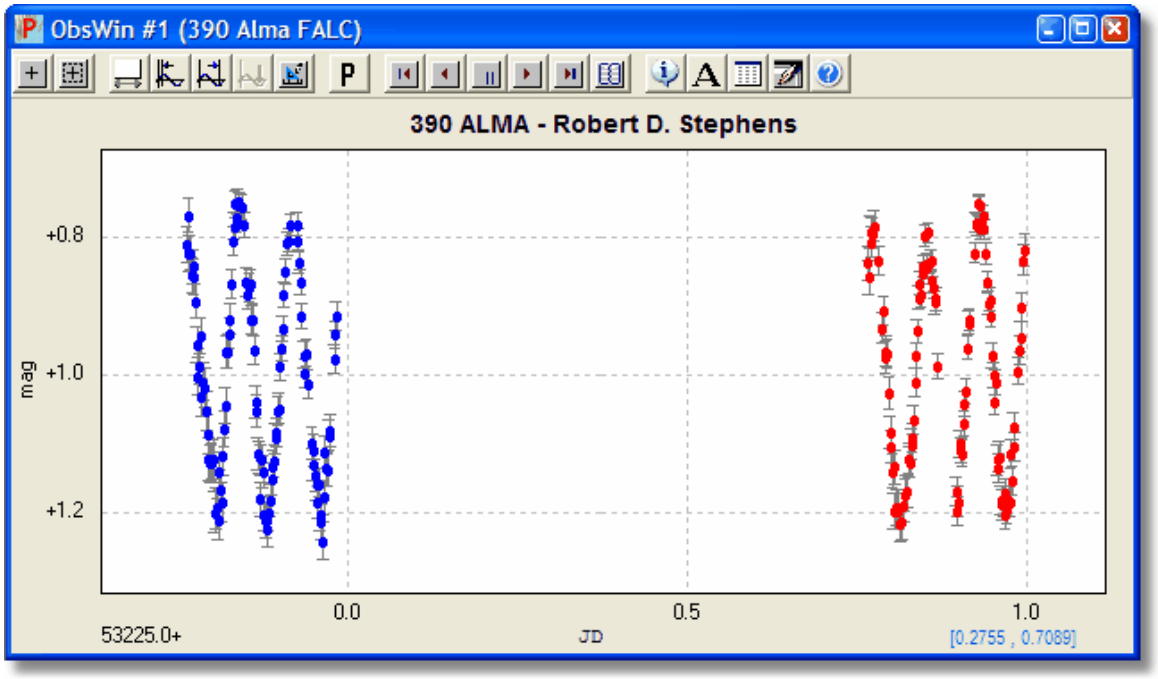

3. The proper alignment of Observation Sets (ObsSets) is critical to finding the right period, since the FALC method can find a different period for different ObsSet alignments. In many cases, you will have to align ObsSets so that they mesh well together, before you start the period analysis. In this tutorial example, the peaks of the ObsSets are at about the same magnitude value, and no adjustment is needed.

10.1.2 Running FALC from the Period Analysis menu

1. Select **FALC (Harris)** in the **Period Analysis** menu to display the **FALC Parameters** dialog box.

   ⇨ The default base time in *Peranso* is days, which is typical for variable star work. Asteroid period calculations are usually expressed in hours. You can select which base is used with the **Hours** toggle. Activating it will instruct *Peranso* to execute the subsequent period calculation in hours (or cycles per hour).

   ⇨ Enter **start** and **end** values in the **Period** frame to define the period scan range. Enter the **Resolution** value to define the period step size.

   ⇨ The **Unit** frame allows you to toggle between **freq**uency- or **time** domain based calculations.

   ⇨ The **Number harmonics** field defines the number of harmonic orders to be used in the Fourier analysis. If you have sufficient observations (25 or more) that cover a good portion of the light curve, a good starting value is 4. If coverage of the light curve is sparse, e.g., due to large gaps, then use a lower value such as 2.

   ⇨ Finally, you can specify a **Default MagError value**. That will be applied during the FALC period analysis to all observations that have no explicit MagError defined. If no default magnitude error value is specified, or if a value smaller than 0.0001 mag is given, *Peranso* uses 0.0001 mag.

   Enter the values shown in the screen shot below to run the analysis between 2.5 and 4.5 hours, in the Time domain. Click **OK** to start the FALC calculation.

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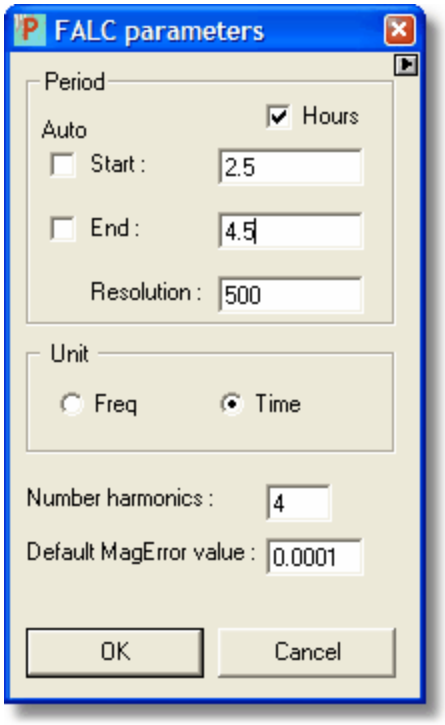
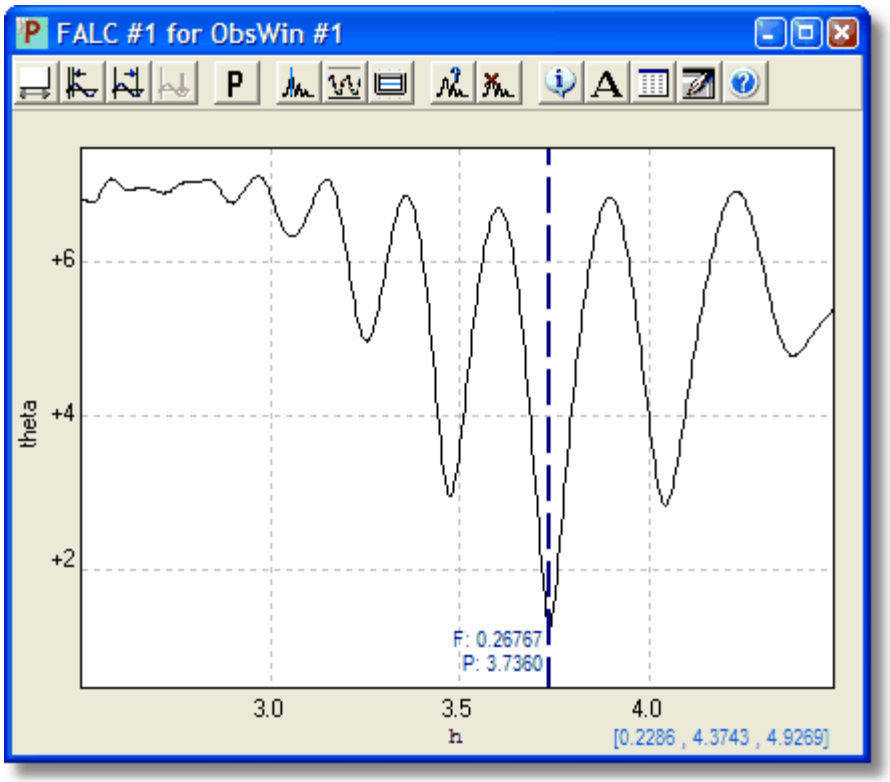


2. This creates a Period Window (PerWin) with caption "*FALC #1 for ObsWin #1*". Valleys correspond with most likely periods. Follow the instructions from Tutorial 1 to determine the dominant period. You will find a value of 3.74 hours, which corresponds very well with literature value (1).



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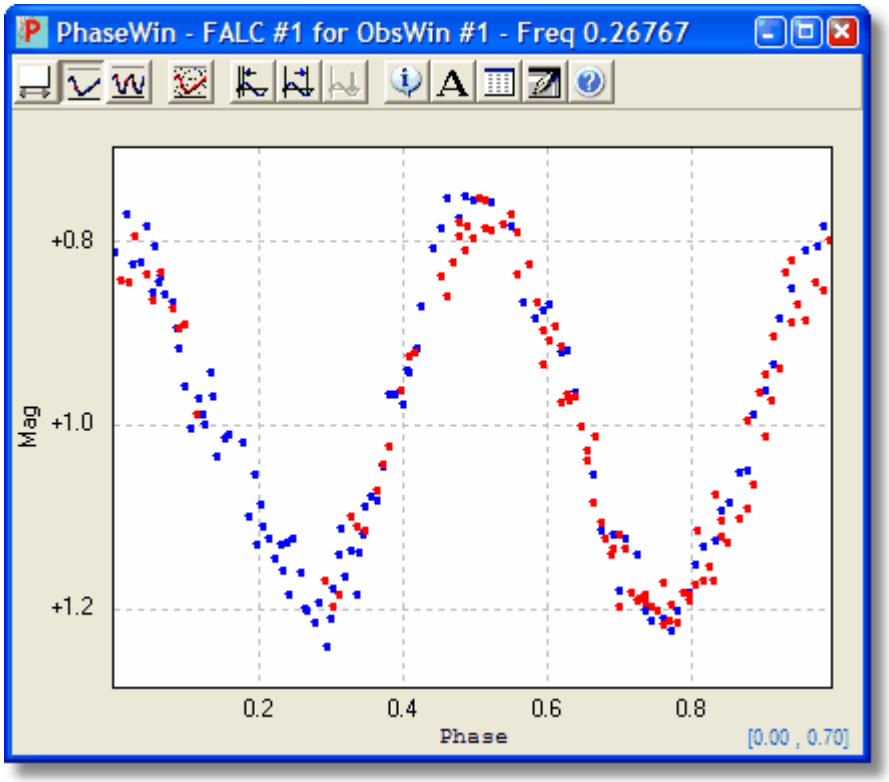
3. Finally, create a Spectral Window (explained in Tutorial 1) to confirm that the period found in this step is not an artifact of the observing rate.

(1) Robert D. Stephens, *Rotational Periods of 96 Aegle, 386 Siegena, 390 Alma, 544 Jetta, 2771 Polzunov, and (5917) 1991 NG*, The Minor Planet Bulletin, 2005, Vol 32, Nr 1

10.1.3 Analysing the Phase Window

1. Select **PhaseWin at Frequency Cursor Value** in the **Period Analysis** menu (or click on in the PerWin Toolbar). This creates a Phase Window (PhaseWin) with caption "*PhaseWin - FALC #1 for ObsWin #1 - Freq 0.26767*", showing the result of folding the *390 Alma* time series data over the dominant period of 3.74 h.

   The PhaseWin furthermore illustrates that both ObsSets have been well aligned and that the dominant period is nicely matching the observations.



2. Select **Info** in the **Phase Window** menu (or click on in the PhaseWin Toolbar) to display the **Info Form** dialog box. It contains the regular *Peranso* info fields, complemented with some FALC specific fields, that indicate :

   ⇨ the number of harmonics, and
   ⇨ the default MagError value,

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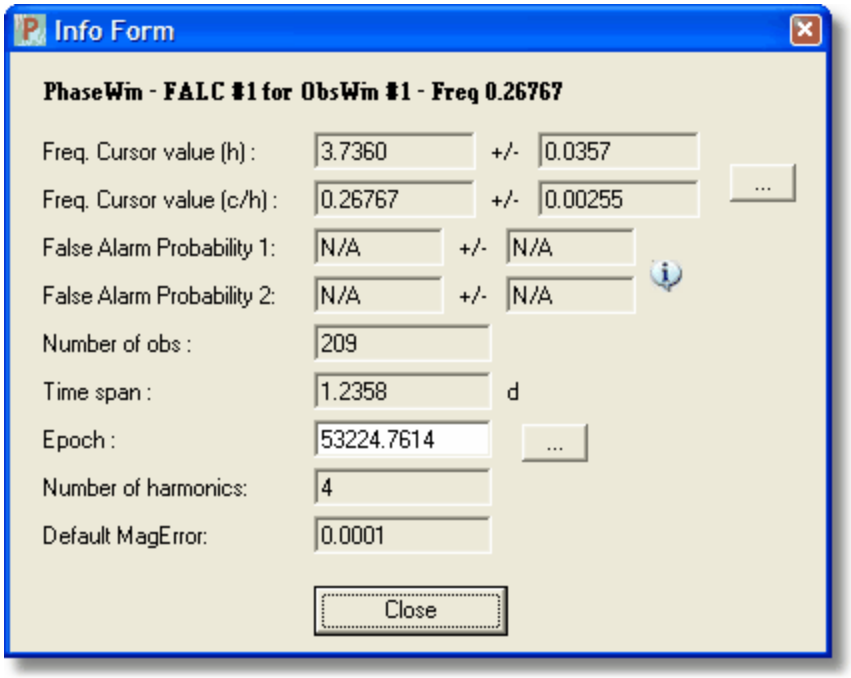
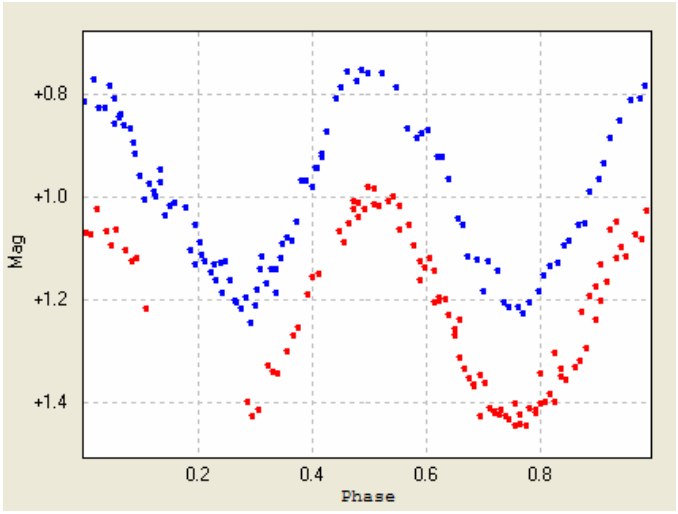
used in the FALC calculations.



3. Next to the **Epoch** field is a button labeled "**...**". You may use this button to change the position of the 0% phase using the **Epoch Form**.

Remark : assume that the *390 Alma* ObsSets would not have been well aligned before starting the FALC period analysis. The resulting PhaseWin then might look as indicated below. The two ObsSets clearly are shifted, which is a good indication that a better alignment is needed. Adjust one of the two ObsSets, then restart the period analysis and create a new Phase Window to assess the results.



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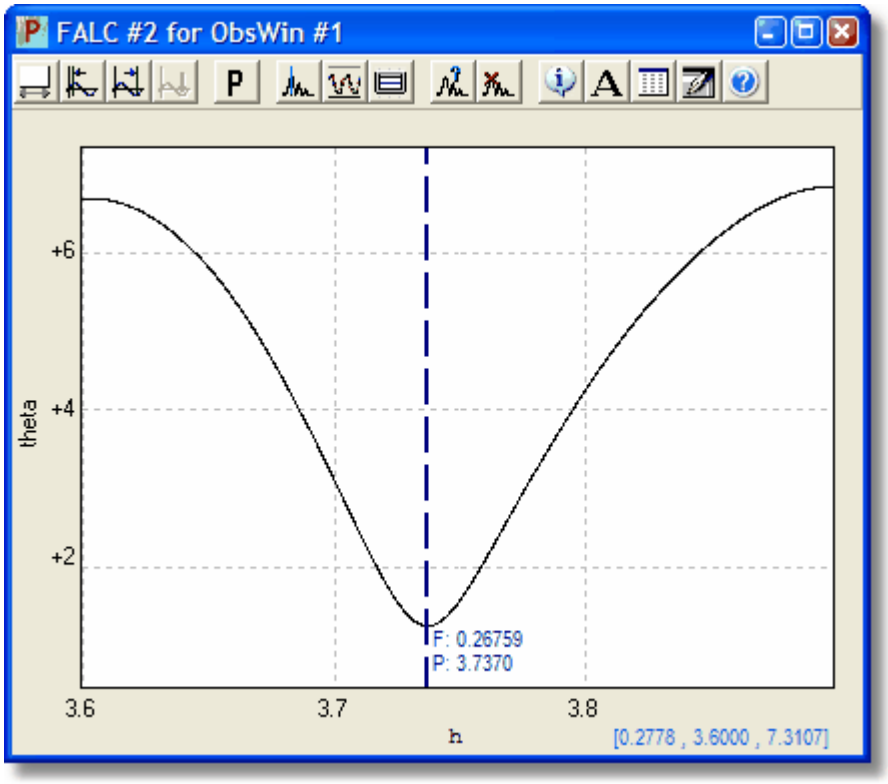
10.1.4 Refining the FALC period analysis

1. Select **Refine Period Analysis** in the **Period Analysis** menu (or click on the Refine Period button P in the PerWin Toolbar) to display the **FALC Parameters** dialog box. Enter a start value of 3.6 hours, an end value of 3.9 hours, and a resolution of 1500 steps. Then click **OK** to start the period calculations. This creates a new Period Window (PerWin) with caption "*FALC #2 for ObsWin #1*". Follow the instructions from Tutorial 1 to determine the new dominant period. You will find a value of 3.7370 hours.



2. Select **Textual View** in the **Period Window** menu (or click on the A button in the PerWin Toolbar) to display the **Textual View** form.

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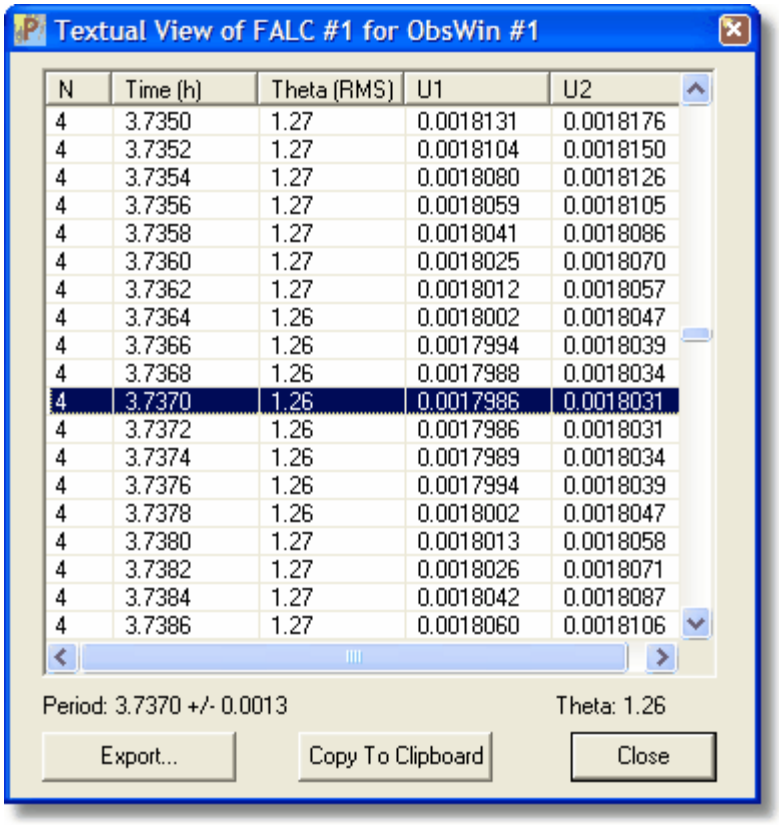

3. The **Textual View** form contains following items :

⇨ A tabular list with numerical values (explained below). The highlight is placed on the line with the best period *Peranso* could find (which is not necessarily the correct period). It is the period with a minimum **Theta (RMS)** value. That value is the RMS (Root-Mean-Square) dispersion, in units of the a priori estimated uncertainty (thus, 1.0 means the fit is exactly as good as you estimated the default magnitude error value to be).
Remark : one should always verify that the dispersion is > 1.0, i.e. better than the formal noise in the data.

⇨ the best **FALC period** and **FALC period error** (period uncertainty). In our example : 3.7370 +/- 0.0013 hours.
Remark : the FALC period error is calculated following the algorithm provided by *Alan Harris* (JPL). It is different from the regular period error method used by *Peranso*, which is based on a method by *Schwarzenberg-Czerny*. The latter is displayed in the Period Window Info dialog box.

⇨ the **Theta (RMS)** value of the best period.

⇨ **Export** button : to save the contents of the tabular list to a text file.

⇨ **Copy To Clipboard** button : to copy the contents of the tabular list to the Microsoft Windows clipboard.

⇨ **Close** button : to hide the Textual View form.

Each line of output in the tabular list includes the fit harmonic order [**N**], the value of the period [

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Time(h)], the RMS (Root Mean Square) dispersion [**Theta(RMS)**] , and two columns of fit uncertainty [**U1**] [**U2**] in units of magnitude.

The first of the two columns of fit uncertainty [**U1**] is the formal uncertainty of the fitted curve, that is, the RMS fit dispersion divided by sqrt[(N)(N-K)], where N is the number of observations, and K is the number of solution constants (1). The second column [**U2**] is the same, except divided by sqrt[(N)(N-K-1)]. The difference between the values in the two columns is a formal measure of significance of changing the solution. Thus if you force the solution off from the minimum value of dispersion by an amount that raises the dispersion in the first column to be equal to the value in the second column at minimum, then you are “one sigma” off of the least squares solution.

Example. The minimum U1 value is about 0.0017986 for a period of 3.73700 hours. The corresponding U2 value is 0.0018031. This is about equal to the U1 value for periods of 3.73600 hours and 3.73820 hours. These values are +/- 0.001 hours from the best fit solution. We therefore infer that the formal uncertainty of the period determined is +/- 0.001 hours.

We will see in Part 2 that we can further try to refine this period, by running an Harmonic Order Scan.

(1) The number of solution constants is (2 * N + NbrObsSets), where N is the harmonic order and NbrObsSets is the number of ObsSets in your light curve. Example : if N = 4 and you use 4 ObsSets, then the number of solution constants is 12. You should always ensure that the total number of observations in your light curve is at least double of the number of solution constants.

10.2 Part 2. Using the FALC method from the FALC Workbench

A more advanced way of using the FALC method is through the **FALC Workbench**. The period finding routine in this workbench is a quasi-direct translation of the FORTRAN program, *FALC*, developed by Dr. Alan W. Harris (JPL). What follows are parts of his explanatory text for the program, modified to fit the user interface in *Peranso*.

1. Select **Open** in the **File** menu (or click on in the main Toolbar) to display the **File Open** dialog box. Navigate to the *Peranso Tutorials* folder, which by default is located in the *Program Files* folder, where also *Peranso* is located. Select the file "*45 Eugenia FALC*" and click the **Open** button.

2. This loads the contents of the file and creates an Observations Window (ObsWin) with caption "*45 Eugenia FALC*". It contains 4 Observation Sets (ObsSets) and a total of 26 observations.

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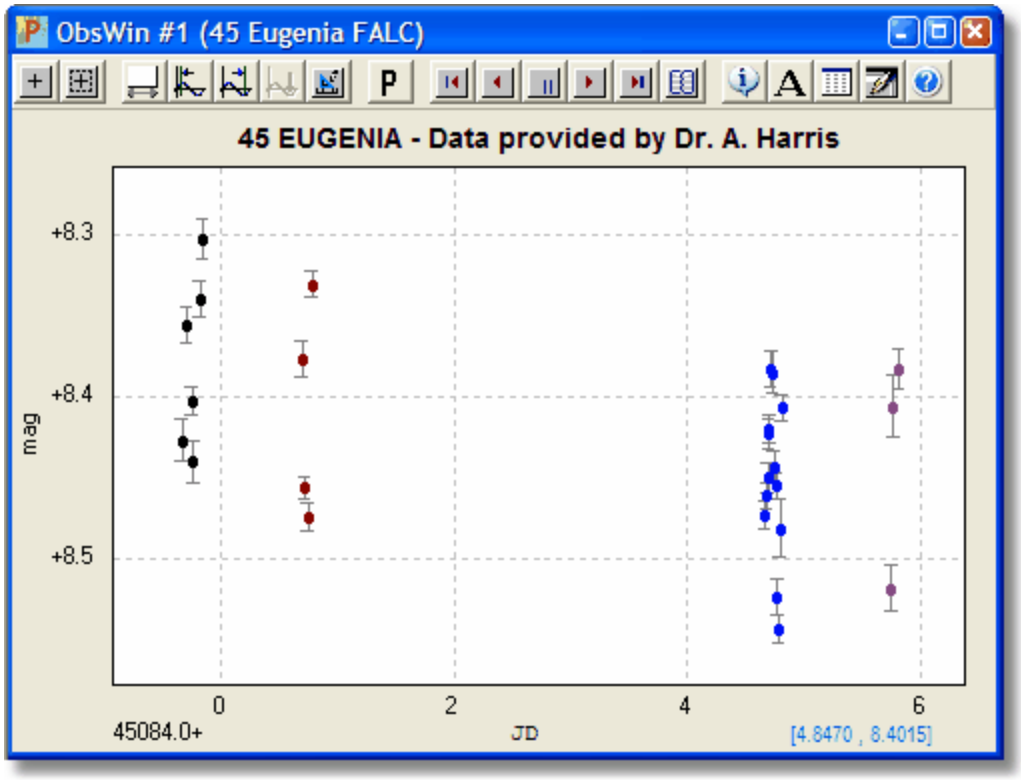
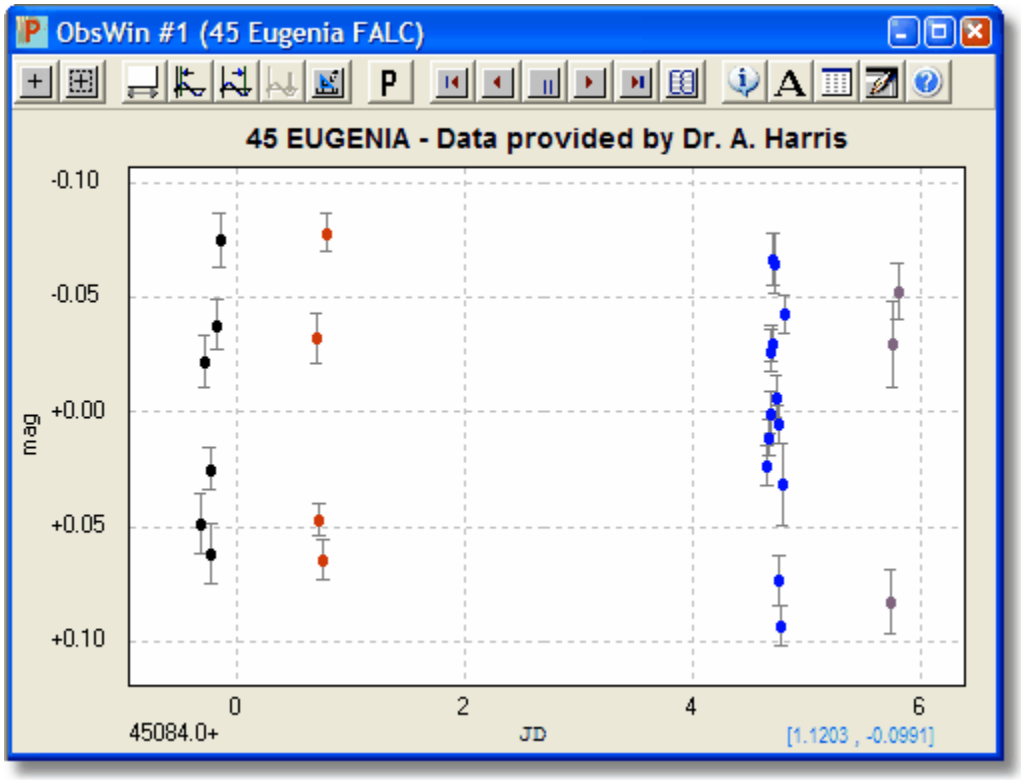


3. We have to adjust the ObsSets before starting the FALC analysis, using the Subtract Avg Mag All command.



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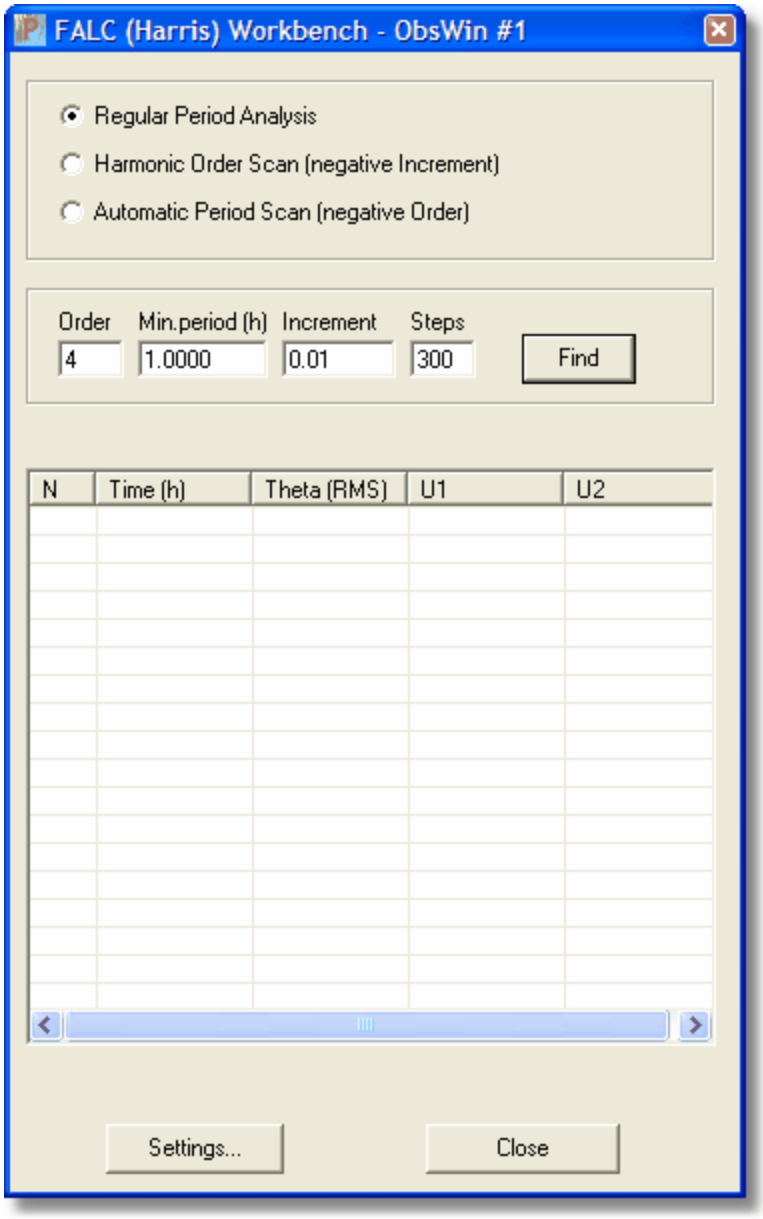
4. Select **FALC (Harris) Workbench** in the **Tools** menu to display the **FALC (Harris) Workbench**.



5. At the top of the form, you are presented a choice of 3 analysis methods :

- Regular Period Analysis
- Harmonic Order Scan (negative Increment)
- Automatic Period Scan (negative Order)

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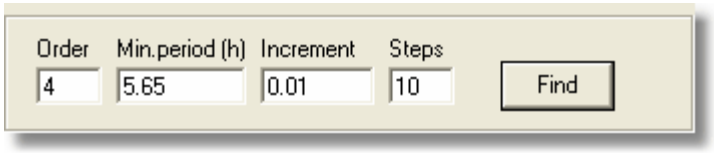
10.2.1 Regular Period Analysis

There are several ways to approach a period search. If you have a good idea of the period, you can start with a value that is slightly under that, and scan a series of periods. This 'regular' period analysis is almost similar to the approach you would follow when starting a FALC analysis from the Period Analysis menu (Part 1).

1. Asteroid *45 Eugenia* has a known period of 5.699 hours. Let's see how close we can get to this result, using the limited number of observations from our tutorial sample. We use the FALC Workbench, with following entries. Click the **Find** button to start the calculation.



⇨ **Order** : this defines the number of harmonic orders in the Fourier analysis. If you have sufficient observations (25 or more) that cover a good portion of the light curve, a good starting value is 4. If coverage of the light curve is sparse, e.g., due to large gaps, then use a lower value such as 2.

You can enter a negative number in this field. In this case, *Peranso* does an Automatic Period Scan. This is helpful when you don't have an initial good guess of the period.

⇨ **Min. period (h)** : enter the minimum period in hours, from which to start the analysis.

⇨ **Increment** : enter the increment in hours between one trial period and the next. If you enter a negative value, *Peranso* will perform an Harmonic Order Scan.

⇨ **Steps** : enter the number of periods to try. If you enter a positive value in the Orders field, the highest period is Min. period + (Steps – 1) * Increment.

⇨ Click the **Find** button to display a Period Window showing the "theta" (dispersion RMS) values for each trial period. In addition, the **FALC Workbench** table will be updated, to show a textual representation of the calculated periods. We refer to Part 1 "Refining the FALC period analysis" for an explanation of the column meanings. The highlight in the table will be placed on the line with the best period *Peranso* could find. This is not necessarily the correct period.

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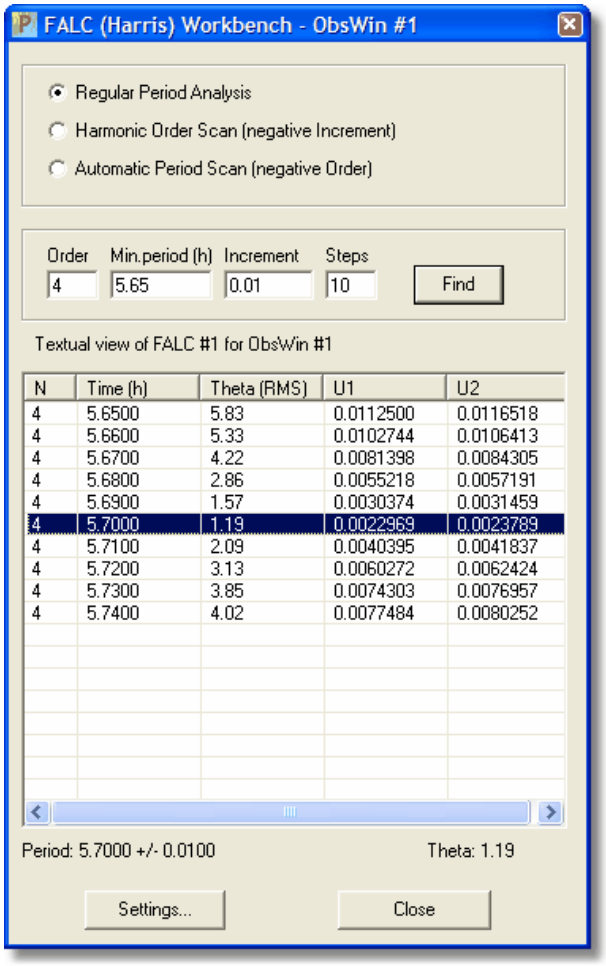
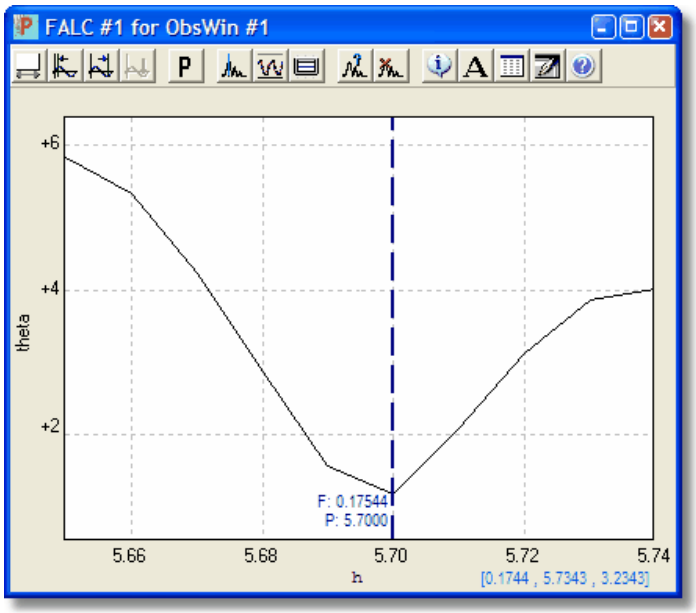


2. This creates a Period Window (PerWin) with caption "*FALC #1 for ObsWin #1*" and with a dominant period at 5.700 hours.



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3. Do a more detailed scan, starting with a **Min. period (h)** of 5.695, an **increment** of 0.001 and 10 **steps**. Try this yourself. You should now get a refined period of 5.6970 hours, with an uncertainty of +/- 0.0025 hours.

There is one other item to be mentioned. It relates to the choice of the scan intervals (Increment) to try in period searching. The objective is to sample periods often enough that successive solutions will not differ by too much, that is, you won't skip over a minimum in the dispersion function without noticing it. To avoid wasting time oversampling, you have to choose an Increment such that successive period choices differ by less than about 1/10 of a cycle over the entire data span. Thus,

*Increment = 0.1 * (P^2 / T)*
where T is the time span of the data.

Example, if T = 125 hours and P =5.7 hours,
Increment = 0.1 * (5.7*5.7 / 125) = 0.026 hours

If your computer is slow and your data set is large, you can get away with this large of a step size. To be safe, it's best to stay a bit lower.

10.2.2 Harmonic Order Scan

The next scan that should be performed is in harmonic order. Enter the best fit period (5.697 hours in our tutorial example) in the **Min. period (h)** field, and select **Harmonic Order Scan** or enter a negative scan **Increment**. This tells *Peranso* to hold the period constant and to try different values of Orders, starting with the number entered in the **Order** field and increasing by 1 for **Steps** number of times.

This allows you to see whether or not higher values of Orders can produce less dispersion and at which point, if any, increasing the value of Orders is no longer justified.

1. Enter the values below in the FALC Workbench and click on **Find**.

2. No Period Window is displayed, but the values in the FALC Workbench table are updated.

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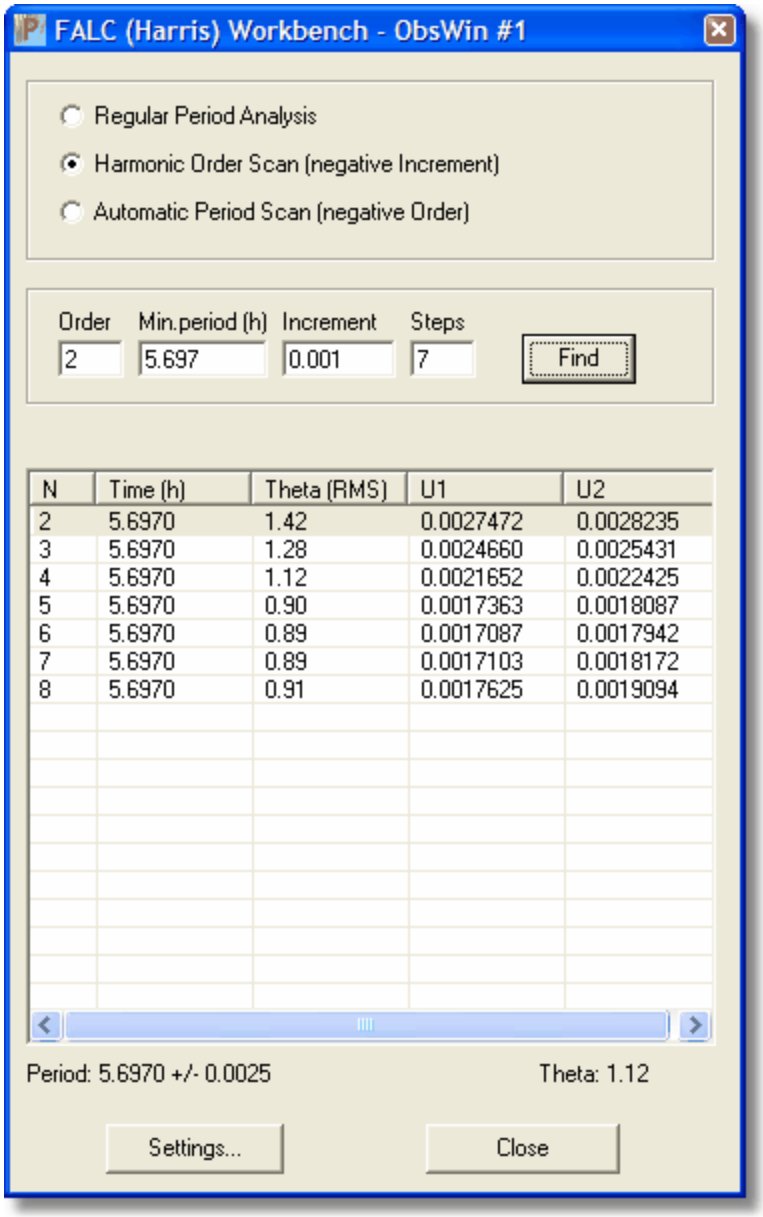

3. Formally, we get a better RMS value for N = 5 than 4, but one should be cautious here, because the RMS falls under 1.0, that is, it is better than the formal noise in the data. Notice that increasing the order of fit fails to improve things beyond about 6 and in fact makes it worse for N = 8 (1).

   To decide if an additional harmonic is formally significant, you can use the two columns of fit uncertainties **U1** and **U2** again, but this time keep in mind that each harmonic order introduces TWO new solution parameters. Therefore, the fit uncertainty has to improve by twice the difference in the two columns to be significant.

   So, let's analyse this for N = 5 first. We find |U1 – U2| = 0.0000724, and twice this value is 0.0001448. Between order 4 and 5, the fit uncertainty improved by 0.0021652 – 0.0017363 = 0.0004289, which is more than 0.0001448. So formally the fifth harmonic is significant, but with the above word of caution.

   Is the 6th harmonic significant ? We find |U1 – U2| = 0.0000855, and twice this value is 0.000171.

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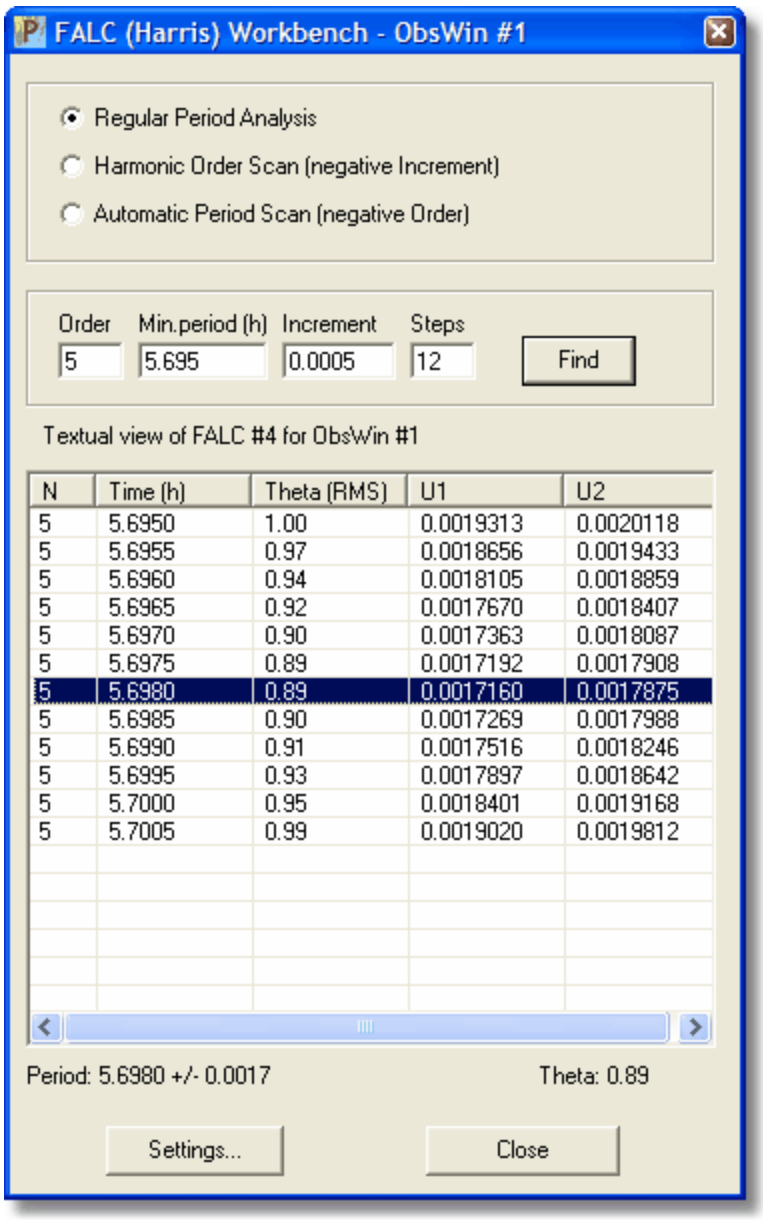
Between order 5 and 6, the fit uncertainty improved by 0.0017363 – 0.0017087 = 0.0000276, which is less than 0.000171. We conclude that the 6th harmonic is no longer significant.

4. One last refinement now is to do another period scan for N = 5, using a Regular Period Analysis, to really home in on the period value. We find the dominant period for *45 Eugenia* at 5.6980 hours, with an uncertainty of 0.0017.



(1) This is because of the factor sqrt[(N)(N-K)] in the denominator, and K increases with added solution parameters.

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10.2.3 Automatic Period Scan

What if you have no idea what the period may be ? Another feature of *Peranso* allows you to scan a really large range of periods efficiently. Since the period Increment scales as inverse period squared, it is efficient to increase the Increment as the trial period gets longer.

Select **Automatic Period Scan** or enter a negative Order, to tell *Peranso* that you will be scanning over a large range of periods, so the period Increment will be increased proportional to 1/P^2 (P being a trial period) as it goes along.

A look at the individual ObsSets of *45 Eugenia* would reveal that the period could hardly be less than 3 hours. An increment of about 0.005 hours would be safe at such a short period. So, our FALC Analysis could look like this :

Peranso finds a dominant period at 5.703 +/- 0.014 hours, showing that the correct period hasn't been missed. Note that the Increments are much larger towards the end of the period scan than at the beginning.

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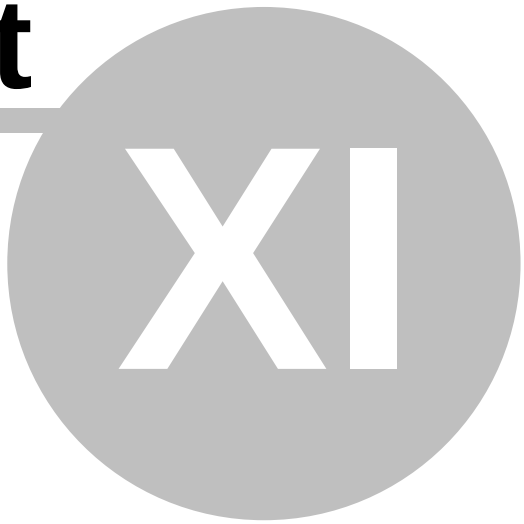
Part



11 The Peranso Desktop Window

The *Peranso* Desktop Window is the 'workspace' for all other *Peranso* windows and dialog boxes, and all of them appear inside the screen size occupied by the Desktop Window. The Desktop Window consists of :

- File Menu
- Tools Menu
- Window Menu
- Help Menu
- a Toolbar

11.1 File Menu

11.1.1 New

Creates an empty Observations Window.

11.1.2 Open

Opens a previously saved Peranso file. A *Peranso* file contains one or more Observations Windows, and all Period Windows and Phase Windows associated with them. The user is presented a standard Microsoft Windows File Open dialog box to navigate to the *Peranso* file to be opened. *Peranso* files have an extension .per or .PER.

In addition, the **Open** command allows to directly import two-column text files (first column contains the Julian Date of the observations, second column their magnitudes). Only two-column text files can be imported with the Open command. To import text files with more than 2 columns, use the Add Observation Set or Add Multiple Observation Sets commands.

11.1.3 Exit

Quits *Peranso*. If a window contains unsaved data, the user will first be presented a possibility to Save the window contents.

11.2 Tools Menu

11.2.1 Julian Day Calculator...

Displays a Julian Day Calculator to compute the Julian Date corresponding to a particular Calendar Date and vice versa.

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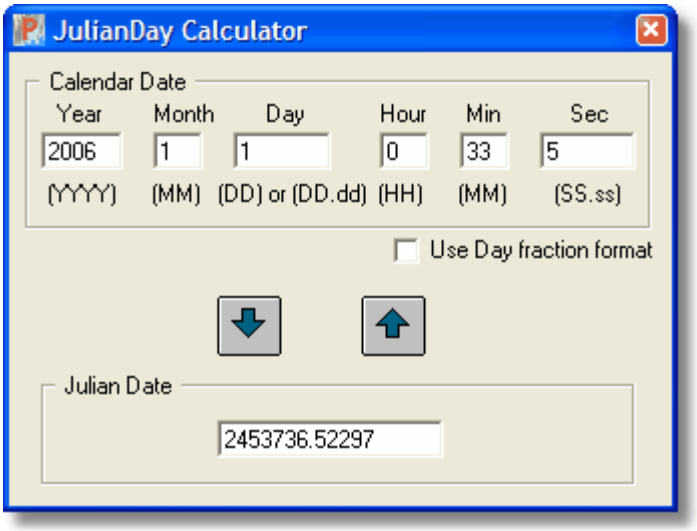

- To convert a Calendar Date to a Julian Date

  Enter the Calendar Date in the frame **Calendar Date**.

  Two options exist :
  1. Enable the **Use Day fraction format** check box first. Enter the day with decimals in the **Day** field, and leave **Hour**, **Min** and **Sec** empty. Click the button. The corresponding Julian Date will appear in the frame labeled **Julian Date**.

  2. Disable the **Use day fraction format** check box and enter the **Year**, **Month**, **Day**, **Hour**, **Minutes** and **Seconds** values as integers. Then click the button, as described above.

- To convert a Julian Date to a Calendar Date

  Enter the Julian Date in the frame **Julian Date** and click the button. The corresponding Calendar date appears in the frame **Calendar Date**.

  If the **Use day fraction format** check box is enabled, the **Day** will be displayed in fractional format (day with decimals). If not, the **Hour**, **Minutes** and **Seconds** fields will be completed.

11.2.2 Exoplanet Diagnostic (Tingley)...

Tingley's **Exoplanet Diagnostic** (1) indicates how "planet-like" a particular transit event is, using only the transit period, duration and depth. This diagnostic makes it possible to exclude many of the candidates from transit searches, without the need for follow-up observations, including many of those caused by blends.

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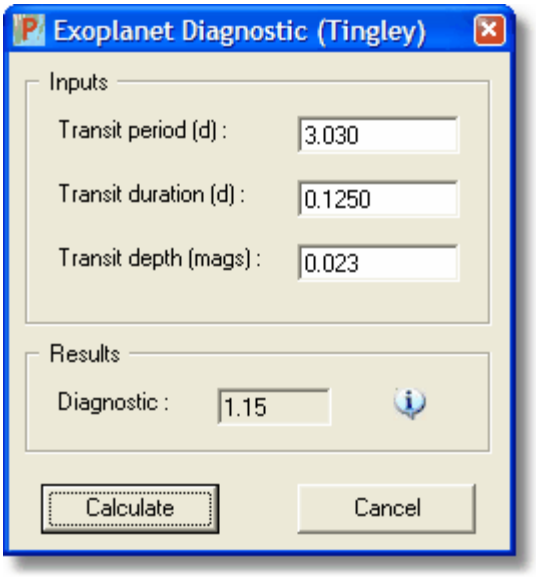

Enter the **Transit period**, **duration** and **depth** in the Inputs frame and click the **Calculate** button. If the resulting **Diagnostic** value is above approx. 1.2, the transit event is most likely not "planet-like". The Exoplanet Diagnostic is integrated as well in the Period Window Info dialog box of the EEBLS method.

Peranso implements formula [11] of Tingley's paper (1). Note that the table at the end of the paper has wrong diagnostic values (2).

(1) http://arxiv.org/PS_cache/astro-ph/pdf/0503/0503575.pdf
(2) Tingley, priv. comm., Oct 2005

11.3 Window Menu

The Window Menu of the *Peranso* Desktop has no active entries.

11.4 Help Menu

Invokes the *Peranso* Help Viewer to browse the comprehensive on-line documentation. The Help Viewer provides an integrated table of contents, an index, and a full-text search feature so you can find information easily. Book icons open to reveal topic entries and sub-books. The Help Viewer has the added benefit of allowing you to see the table of contents, index, or search results at the same time you are viewing a Help topic. This orients you within the Help system and allows you to see all of the other applicable Help topics at a glance.

In the Help Viewer, click one of the following tabs:

- To browse through the table of contents, click the **Contents** tab. Double-click the book icons to reveal topic entries and sub-books. Click a table of contents entry to display the corresponding topic.

- To see a list of index entries, click the **Index** tab, and then either type a word or scroll through the list. Topics are often indexed under more than one entry. Double-click an index entry to display the corresponding topic.

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- To locate every occurrence of a word or phrase, click the **Search** tab, type the word or phrase for which you want to search, and then click List Topics. Double-click a search results entry to display the corresponding topic.

- To bookmark a topic, use the Contents, Index, or Search tabs to locate and then display a topic. Click the **Favorites** tab, and then click **Add** to save the topic title to the Topics list. Double-click a bookmark in the Topics list to quickly display the topic.

11.4.1 Contents...

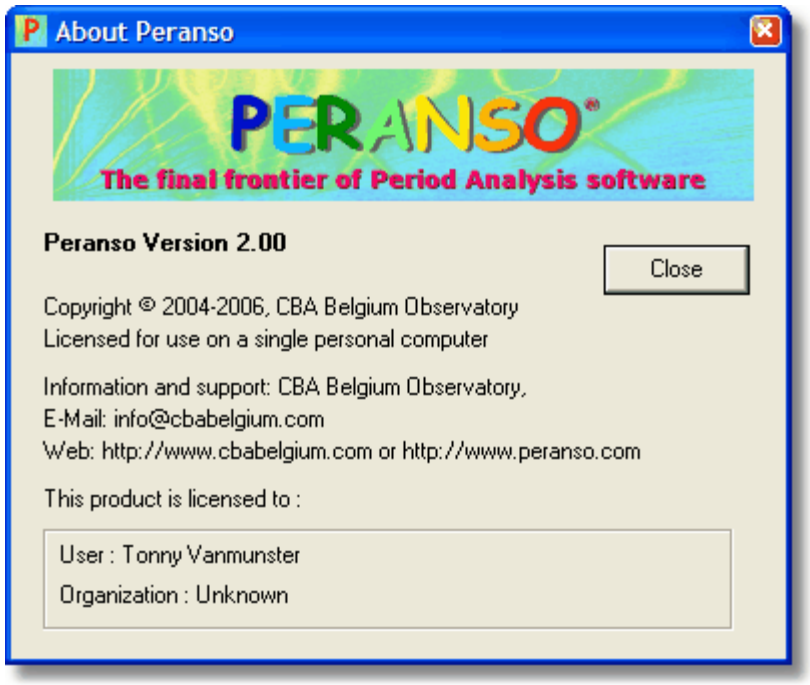
This command invokes the Peranso Help Viewer and opens the **Contents** tab.

11.4.2 Index...

This command invokes the Peranso Help Viewer and opens the **Index** tab.

11.4.3 About Peranso...

Displays the **About Peranso** dialog box, which lists a/o the *Peranso* version number.


About Peranso
PERANSO
The final frontier of Period Analysis software
Peranso Version 2.00
Close
Copyright © 2004-2006, CBA Belgium Observatory
Licensed for use on a single personal computer
Information and support: CBA Belgium Observatory,
E-Mail: info@cbabelgium.com
Web: http://www.cbabelgium.com or http://www.peranso.com
This product is licensed to :
User : Tonny Vanmunster
Organization : Unknown

11.5 Toolbar

The Desktop Window Toolbar groups following commands :

Icon	Command
	New
	Open
	Help

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Part

12 The Observations Window

12.1 File Menu

12.1.1 New

This command is identical to the Peranso Desktop Window New command.

12.1.2 Open

This command is identical to the Peranso Desktop Window Open command.

12.1.3 Close

Closes the active Observations Window and all associated Period Windows and Phase Windows.

If the contents of the Observations Window or its associated windows were changed since the last Save operation, the user will be prompted to first save his work.

12.1.4 Save

This command saves the contents of the *Peranso* Desktop windows (all Observations Windows, Period Windows and Phase Windows) to a *Peranso* file. If no filename had been specified yet by the user, he will first be presented a standard Microsoft Windows File Save dialog box to define the location and filename. That *Peranso* file can be reopened, using the Open command, at a later stage to continue the data analysis under the same conditions as at the moment of the Save operation.

When saving to an existing *Peranso* file, the user will not be prompted again to enter the name of the file. *Peranso* will simply overwrite that file.

12.1.5 Save As...

This command is similar to the Save command, but the user will be prompted to select the location and name of the *Peranso* file in which to store the contents of the *Peranso* Desktop windows.

12.1.6 Page Setup...

Allows to select the page orientation and margin sizes for the *Peranso* window (or dialog box, form, etc.) to be printed.

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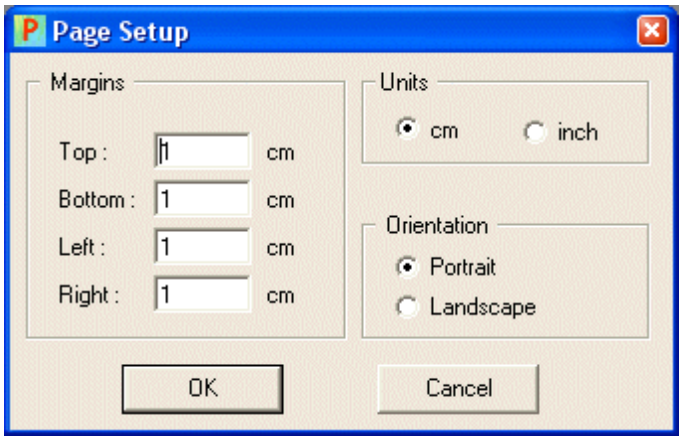


Margins : specifies the margin size on the top, bottom, left and right side of the page to be printed

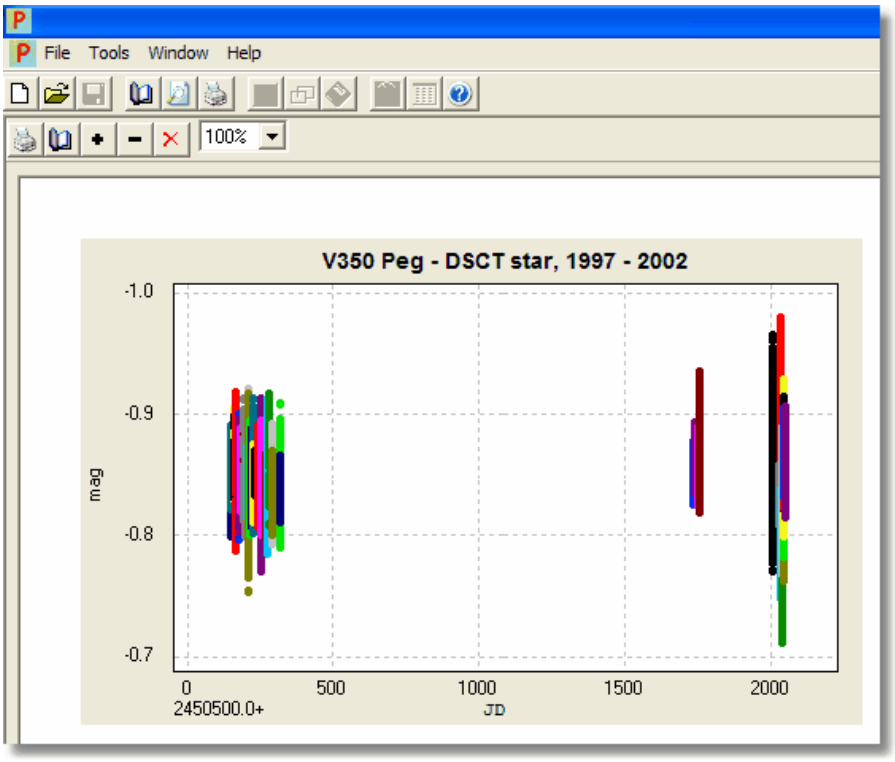
Units : allows to select between 'cm' and 'inch' as the unit for expressing margin sizes

Orientation : allows to switch between 'Portrait' and 'Landscape' printing

Click **OK** to confirm the Page Setup settings, **Cancel** to quit.

12.1.7 Print Preview

Displays the Preview form showing the *Peranso* window (or dialog box, form, etc.) as it will look when printed.



The Preview form contains a toolbar with following buttons :

- **Print** : prints the contents of the Preview form.
- **Page Setup** : allows to modify page setup parameters.
- **Zoom in** : zooms in on the Preview form. This command doesn't change the size of the *Peranso* window (or dialog box, form, etc.) to be printed.
- **Zoom out** : zooms out on the Preview form. This command doesn't change the size of the *Peranso* window (or dialog box, form, etc.) to be printed.
- **Close** : closes the Preview form

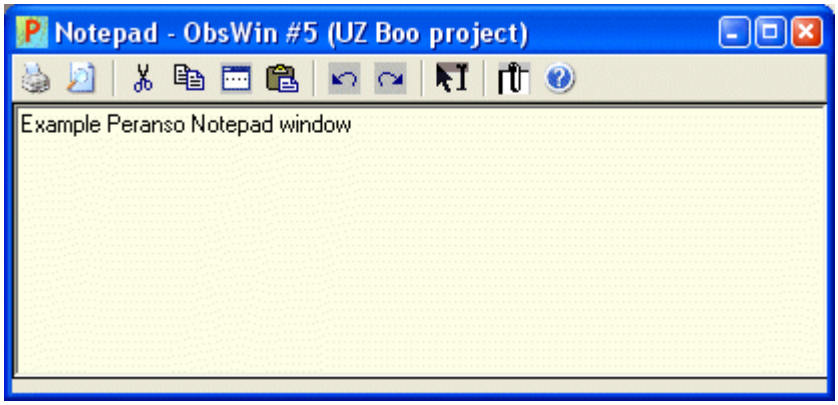
The toolbar also contains a drop down list that allows to zoom in or out on the Preview form using a predefined zoom factor (between 30% and 200%).

12.1.8 Print...

Prints the active *Peranso* window (or dialog box, form, etc) on a graphics printer. The command displays the standard Windows Print dialog box. You can select a printer using the Name field, set up the printer using Properties and select the number of copies to print using Copies, etc.

12.1.9 Notepad

Each basic *Peranso* window has one associated **Notepad** to enter descriptive textual information. *Peranso* stores this descriptive information when a Save operation is executed, and restores the information after an Open operation.



The Notepad toolbar contains following buttons :

- **Print** : prints the contents of the Notepad window.
- **Print Preview** : displays a view that shows how the Notepad contents will look like when you print them.
- **Cut** : clears the selected text and copies it to the Microsoft Windows clipboard.

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- **Copy** : copies the selected text to the Microsoft Windows clipboard
- **Clear** : clears the selected text, but doesn't copy it to the Microsoft Windows clipboard.
- **Paste** : copies the text contents of the Microsoft Windows clipboard in the Notepad window, at the indicated cursor position.
- **Undo** : undoes the most recent action on the Notepad.
- **Redo** : use Redo if you decide you didn't want to undo an action.
- **Select All** : selects the entire text in your Notepad window.
- **Close** : hides the Notepad window (without deleting its contents).
- **Help** : displays the *Peranso* Help Viewer.

12.1.10 Exit

This command is identical to the Peranso Desktop Window Exit command.

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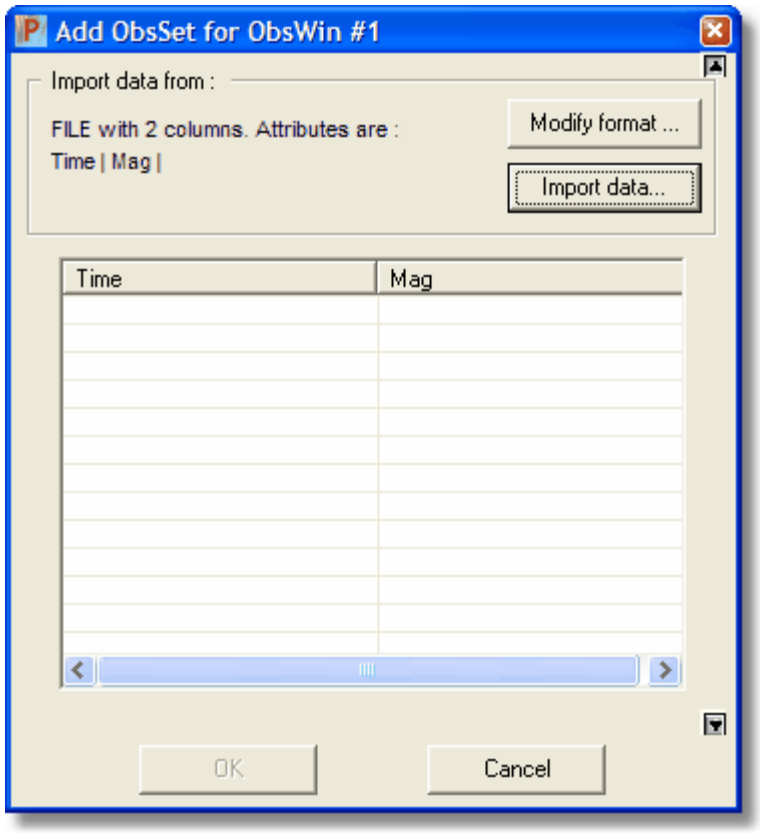
12.2 Observations Window Menu

12.2.1 Add Observation Set...

Reads in a series of observations, creating a new Observation Set (ObsSet), and adds them to the active Observations Window. *Peranso* allows to read in observations from file or to paste them from the Microsoft Windows clipboard, in a wide variety of data formats.



The **Add ObsSet** dialog box exists in two varieties : in a simple form, described in this section, and in an advanced form. In its most simple form, the **Add ObsSet** dialog box appears as above, containing following items :

- A frame **Import data from** : this defines the current data source (FILE or CLIPBOARD) and data format. E.g., "*FILE with 2 columns. Attributes are: Time | Mag |*" specifies that observations will be read from a FILE containing two-columns with resp. time and magnitude values.
- **Modify format** : click this button to display the Modify column format dialog box, used to modify the data source and/or data format.
- **Import data** button : click this button to import data from FILE in the format specified by the **Import data from** description. A standard Microsoft Windows File Open dialog box appears and allows to navigate to the file with observations. Upon reading the observations from file, they appear in the 'preview' table (center of Add ObsSet dialog box).
  The **Import data** button is only visible if the data source is FILE.

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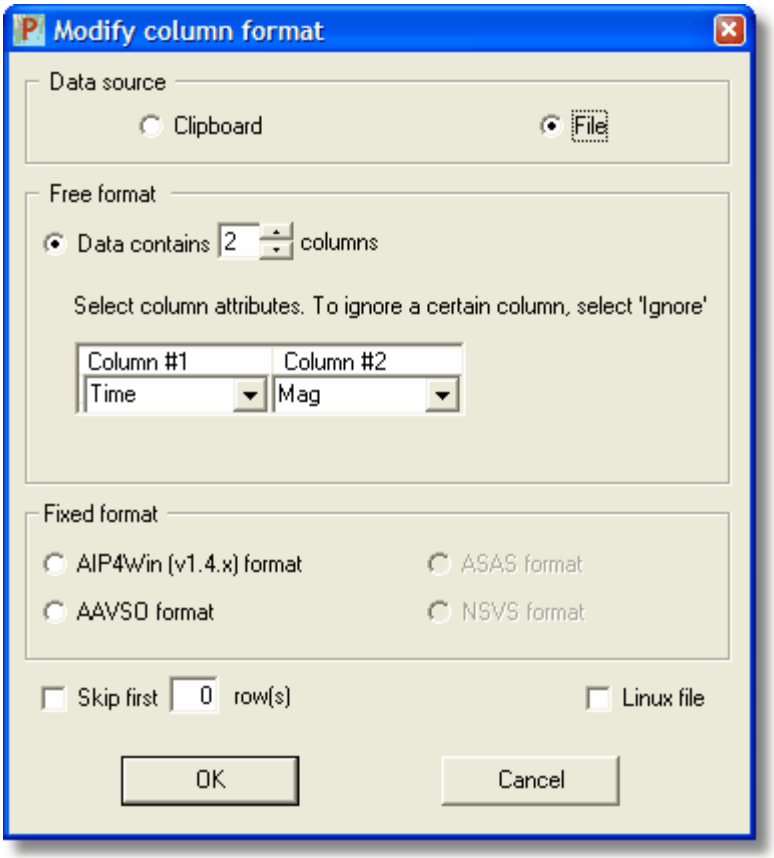
- **Paste data** button : click this button to paste data from the Microsoft Windows CLIPBOARD in the format specified by the **Import data from** description. Upon pasting the observations from the clipboard, they appear in the 'preview' table (center of Add ObsSet dialog box). The **Paste data** button is only visible if the data source is CLIPBOARD.
- a **Preview Table** : after importing observations from FILE, or pasting them from the CLIPBOARD, this Table shows the observations in the defined data format. The number of observations is indicated below the Preview Table.
- **OK** button : adds the observations listed in the Preview Table to the Observations Window as one ObsSet.
- **Cancel** button : closes the Add ObsSet dialog box without creating a new ObsSet.

12.2.1.1 Modify column format

The **Modify column format** command defines the data source (FILE or CLIPBOARD) and data format (column format) to be used when importing observations from file or pasting them from the Microsoft Windows clipboard.



- **Data source** frame : click **File** if you want to import observations from file. Click **Clipboard** if you want to paste observations from the Microsoft Windows clipboard.

- **Free format** frame : the **Free format** frame is to be used when retrieving observations using a column format that you want to define yourself. Use **Fixed format** to retrieve observations from a data source with a predefined column format.

  Use the **Data contains .. columns** field to define the amount of columns in the data source. The column attributes table below the **Data contains .. columns** field will expand / collapse to list the amount of columns that you defined.

  E.g., when reading observations from a file with JD, Magnitude, Magnitude Error and Observer_Name values, enter 4 in the columns field. The column attributes table will show 4 entries, labeled "*Column #1, Column #2, ..., Column #4*".

  Next, define the attribute (or type) of each column, using the drop down menus. Following attributes are supported :

  ⇨ **Time** : the column contains the time of the observation (mostly Julian Date, JD)

  ⇨ **Mag** : the column contains the magnitude of the observation

  ⇨ **MagError** : [optional] the column contains the error in magnitude estimate. A MagError value is visually represented as a 'vertical bar' centered around the corresponding magnitude dot in the light curve. Magnitude error values are taken into account when performing a period analysis calculation using the FALC method.

  ⇨ **Use** : [optional, default = 1] has a value of 0 or 1 and determines if an observation is considered to be active (1) or inactive (0). Inactive observations are not taken into account when performing a period analysis calculation. Observations can be made active and inactive at every moment, using the mouse and keyboard. An active observation is plotted as a filled circle in an Observations Window. Inactive observations appear as open circles.

  ⇨ **Ignore** : the column contains entries that will be further ignored by *Peranso*. They do not become part of the ObsSet.

  In our example above, the column attributes table will be : Time | Mag | MagError | Ignore.

- **Fixed format** frame : the **Fixed format** frame is to be used when retrieving observations from a data source with a predefined column format. Use **Free format** to retrieve observations from a data source for which you define yourself the column format. Following fixed formats are supported :

  ⇨ **AIP4Win (v1.4.x) format** : select this option if your data source is a file produced by AIP4WIN v1.4. This option is only available if you have selected **File** in the **Data source** frame. An example AIP4WIN format file is shown in appendix 1.

  ⇨ **AAVSO format** : select this option if your data source is a file generated through the AAVSO web site, using their *Download data* option in the section *Access Data*. *Peranso* will automatically skip all comment lines. This option is only available if you have selected **File** in the **Data source** frame. An example AAVSO format file is shown in appendix 2.

  ⇨ **ASAS format** : select this option to paste data from the Microsoft Windows clipboard in ASAS (All Sky Automated Survey) format. This option is only available if you have selected **Clipboard** in the **Data source** frame. An example ASAS format is shown in appendix 3.

  ⇨ **NSVS format** : select this option to paste data from the Microsoft Windows clipboard in

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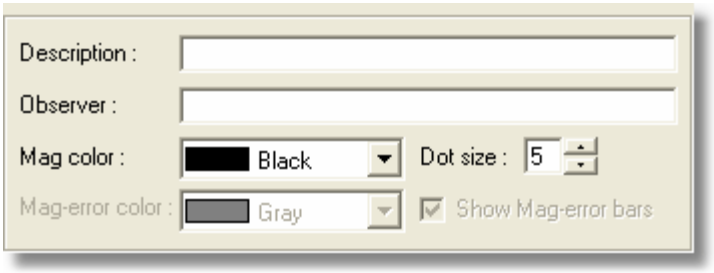
NSVS (Northern Sky Variability Survey) format. This option is only available if you have selected **Clipboard** in the **Data source** frame. An example NSVS format is shown in appendix 4.

- **Skip first .. rows** : select this option if the data source file contains a number of starting comment lines ('rows'), that you want to skip during import. Indicate the amount of comment lines to be skipped.
- **Linux file** : Linux files use special "line delimiters", that are different from Microsoft Windows line delimiters. Enable the **Linux file** toggle when working with a Linux file.
- **OK** : closes the **Modify column format** dialog box and accepts the defined data source and data format. The **Import data from** field in the Add ObsSetdialog box will be updated to reflect your choices.
- **Cancel** : closes the **Modify column format** dialog box.

12.2.1.2 Advanced Options

The upper right corner of the Add ObsSet dialog box displays a button to expand the window. Click the button again to collapse the dialog box. In its expanded form, following new items appear :



- **Description** : an optional text field that describes (in free format) the observation set. The description can still be modified afterwards.
- **Observer** : an optional text field that defines the name of the observer(s). This field can still be modified afterwards.
- **Mag color** : a drop down menu with a set of 15 predefined colors. The selected color is used to draw the observations. The Mag color can still be modified afterwards.
- **Dot size** : an up-down field with 5 predefined values. The selected value defines the thickness of the observation circles, drawn in the Observations Window.
- **Mag-error color** : this field is only active if the data source (FILE or CLIPBOARD) contains Magnitude Error values. It is a drop down menu with a set of 15 predefined colors. The selected color is used to draw the magnitude error bars and can still be modified afterwards.
- **Show Mag-error bars** : this field is only active if the data source (FILE or CLIPBOARD) contains Magnitude Error values. If enabled, then the ObsSet will be drawn with magnitude error bars.

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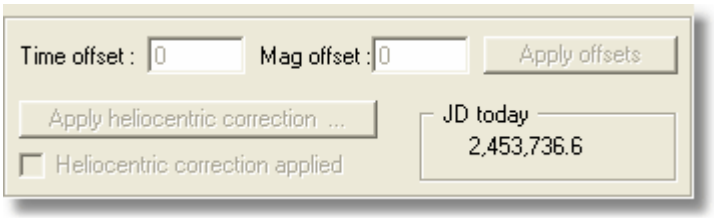
The lower right corner of the Add ObsSet dialog box displays a button to expand the window, with following new items :



- **Time offset** : once the ObsSet has been imported in the Preview Table, you may use the **Time offset** field to indicate a constant time correction to be applied to the time values displayed in the Preview Table. Click **Apply offsets** to apply the correction.
- **Mag offset** : once the ObsSet has been imported in the Preview Table, you may use the **Mag offset** field to indicate a constant magnitude correction to be applied to the magnitude values displayed in the Preview Table. Click **Apply offsets** to apply the correction.
- **Apply offsets** : applies the defined **Time offset** and **Mag offset** values to the observations listed in the Preview Table.
- **Apply Heliocentric correction** : click this button to apply an heliocentric correction to the time values displayed in the Preview Table, using the Star identification command.
- **Heliocentric correction applied** : enable this check box if your observations already were heliocentric corrected before import. *Peranso* automatically enables this check box if you execute the **Apply heliocentric correction** command.
- **JD today** : this is a read-only field displaying the current Julian Date.

12.2.1.2.1 Star identification

To apply an heliocentric correction, *Peranso* requires the Right Ascension and Declination (J2000.0) coordinates of the related object. The **Star identification** form allows to :

- enter the coordinates directly in the **R.A.** and **Decl.** fields of the form, or
- to retrieve the coordinates from the *General Catalogue of Variable Stars* (GCVS), using the name of the variable. Enter that name in the **Variable star name** field and click the **Get coordinates** button. If a correct name has been entered, the corresponding coordinates will appear in the **R.A.** and **Decl.** fields.

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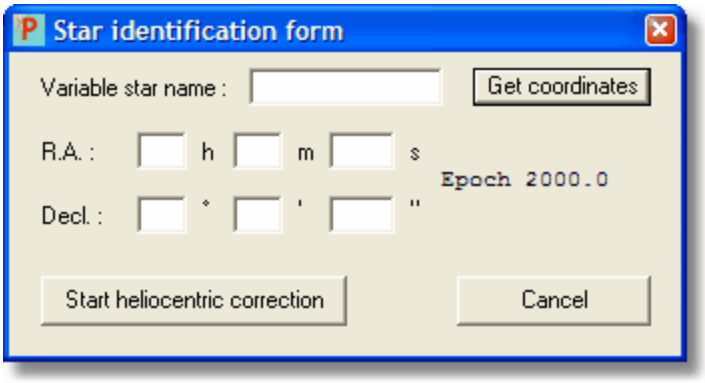
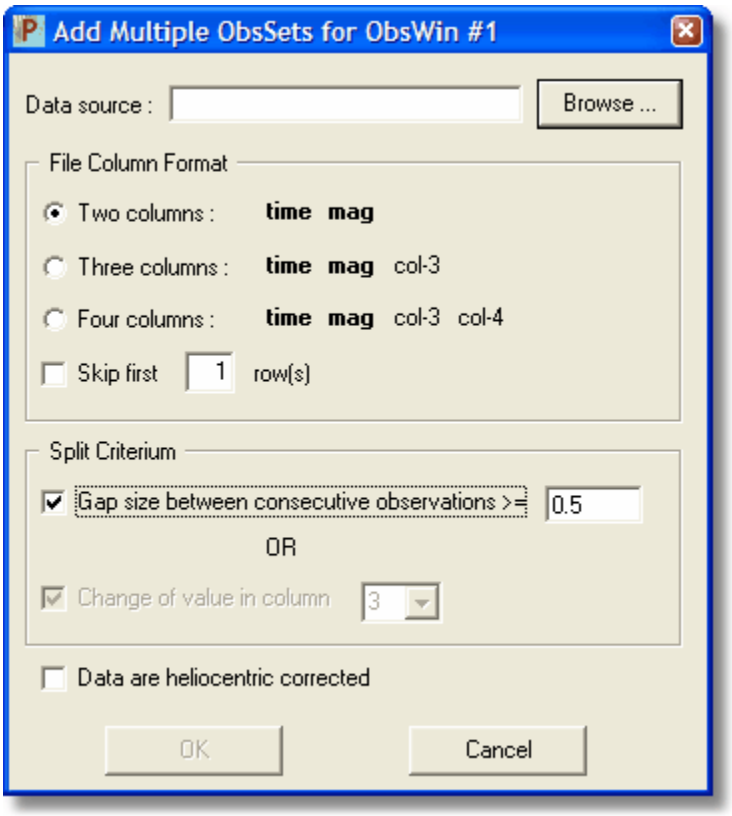


Click the **Start heliocentric correction** button to calculate the time correction values. The Preview Table will be updated to reflect the corrected times. Click **Cancel** to abort the above operation.

12.2.2 Add Multiple Observation Sets...

Reads in observations from file, splits them in multiple Observation Sets, and adds them to the active Observations Window.



The Add Multiple Observation Sets dialog box contains following items :

- **Data source** : defines the location of the file containing the observations to be added to the

active Observations Window. Enter the name of the file directly, or use the **Browse** button to locate the file. The Clipboard can not be used in the Add Multiple Observation Sets command.

- **Browse** : displays a standard Microsoft Windows File Open dialog box, used for selecting the file with observations.

- **File Column Format** frame :

  ⇨ **Two columns** : select this option if the file contains observations with attributes time and magnitude only (in that order).

  ⇨ **Three columns** : select this option if the file contains observations with 3 attributes, of which time and magnitude are the first two (in that order). The third attribute will be ignored during import.

  ⇨ **Four columns** : select this option if the file contains observations with 4 attributes, of which time and magnitude are the first two (in that order). The third and fourth attribute are ignored during import.

  ⇨ **Skip first .. rows** : select this option to define the number of starting comment lines (‘rows’), to be skipped during import.

- **Split Criterium** frame : determines how to distinguish between consecutive observation sets in the file. *Peranso* offers two criteria to indicate the start of a new observation set :

  ⇨ **Gap size between consecutive observations** : a new observation set is started if the time gap between consecutive observations is larger than or equal to the value expressed in the text box. Enable this criterium by clicking the check box in front.

  ⇨ **Change of value in column** : a new observation set is started if a change of value is detected in the indicated column (either column 3 or 4). This method can only be used if you have selected either **Three columns** or **Four columns** in the **File Column Format** frame. Enable this method by clicking the check box in front.

  If both criteria are selected, then a new observation set is started each time at least one criterium applies.

- **Data are heliocentric corrected** : enable this check box if the dates of your observations already were heliocentric corrected before import.

- **OK** : click this button to add the observation sets to the active Observations Window.

- **Cancel** : click this button to cancel the Add Multiple Observation Sets command.

12.2.3 Observation Sets

This menu groups a number of commands that operate on all observation sets of the current ObsWin at once.

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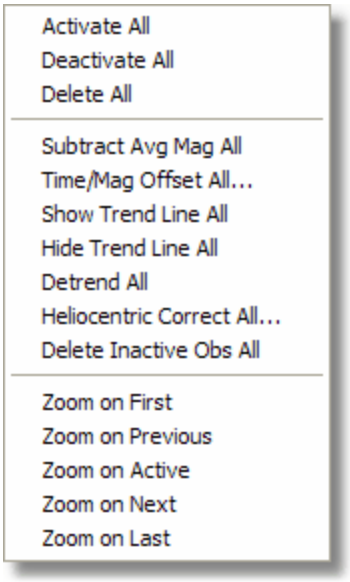

- **Activate All**

  Makes all observations of the current Observations Window active, meaning they will be included in all *Peranso* analysis commands.

- **Deactivate All**

  Makes all observations of the current Observations Window inactive, meaning they will be excluded from all *Peranso* analysis commands.

- **Delete All**

  Deletes all observations of the current Observations Window. This operation can not be undone.

- **Subtract Avg Mag All**

  For each observation set in the current Observations Window, calculates the average magnitude and subtracts it from all observations in that set. This is one way of aligning observation sets before executing a period analysis.

- **Time/Mag Offset All…**

  Allows to apply a constant time and magnitude correction to all observations in the current Observations Window.

- **Show Trend Line All**

  For each observation set in the current Observations Window, fits a line through all observations, using the least squares method. The color, size and style of the trendline can be defined using the Properties dialog box.

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- **Hide Trend Line All**

  Hides the trend line, calculated by the **Show Trend Line All** command.

- **Detrend All**

  For each observation set in the current Observations Window, calculates the linear trend of all observations (using the least squares method) and subtracts it from the observations.

- **Heliocentric Correct All…**

  Displays the Heliocentric Correct All Observation Sets dialog box, used for applying a heliocentric correction to all observation sets of the current Observations Window.

- **Delete Inactive Obs All**

  Permanently deletes all inactive observations from all observation sets in the current Observations Window.

- **Zoom on First**

  Zoom in on the first observation set of the current Observations Window. To again display all observation sets, use the Full View command.

- **Zoom on Previous**

  Zoom in on the observation set that precedes the current one. Observation sets are ordered following their order of definition. To again display all observation sets, use the Full View command.

- **Zoom on Active**

  Zoom in on the active observation set. This is the observation set on which you have last executed an operation. To again display all observation sets, use the Full View command.

- **Zoom on Next**

  Zoom in on the observation set that follows the current one. Observation sets are ordered following their order of definition. To again display all observation sets, use the Full View command.

- **Zoom on Last**

  Zoom in on the last observation set of the current Observations Window. To again display all observation sets, use the Full View command.

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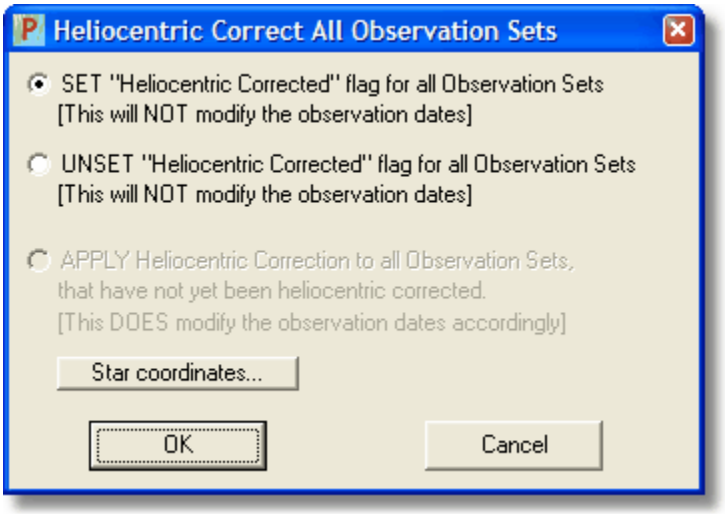
12.2.3.1 Heliocentric Correct All Observation Sets


Heliocentric Correct All Observation Sets
SET "Heliocentric Corrected" flag for all Observation Sets
[This will NOT modify the observation dates]
UNSET "Heliocentric Corrected" flag for all Observation Sets
[This will NOT modify the observation dates]
APPLY Heliocentric Correction to all Observation Sets,
that have not yet been heliocentric corrected.
[This DOES modify the observation dates accordingly]
Star coordinates...
OK
Cancel

- **SET Heliocentric Corrected flag for all observation sets** : turns on the 'heliocentric corrected' flag for all observations in the current Observations Window, indicating that they have been heliocentric corrected. This option does not modify the time of the observations. It simply sets the "heliocentric corrected" flag.

- **UNSET Heliocentric Corrected flag for all observation sets** : turns off the 'heliocentric corrected' flag for all observations in the current Observations Window, indicating that they have not been heliocentric corrected. This option does not modify the time of the observations. It simply unsets the "heliocentric corrected" flag.

- **APPLY Heliocentric Correction to all observation sets** : applies an heliocentric correction to all observations of the current Observations Windows, hence modifying their time. The calculation is only applied to observations that have not been 'heliocentric corrected' before (i.e., whose ' heliocentric corrected' flag is off). Upon completion of the operation, the 'heliocentric corrected' flag of each observation is on.

  This operation requires the Right Ascension and Declination (J2000.0) coordinates of the related object, and therefore a user first has to click the **Star coordinates** button. This displays the Star Identification form (see Add Observation Set command). Once the star coordinates are known, the **APPLY Heliocentric Correction** option becomes selectable.

12.2.4 Overlays...

Overlays are graphical items, drawn on top of a *Peranso* basic window type, and serve multiple purposes. They can be used to mark an interval for extremum calculations, to visualize a polynomial fit through a set of observations, to plot magnitude errors, and so on. *Peranso* supports a wide variety of Overlays.

The **Overlays** command displays a tabular overview of all overlays related to current Observations Window. It lists the **type** of overlay, the ovelay **id**entification, the **line color** and **line width** used to

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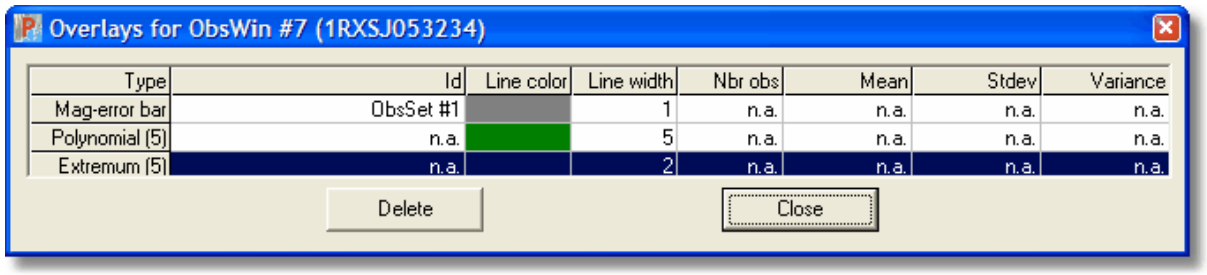
draw the overlay, and additional information.

Use **Delete** to permanently delete the selected overlay. Use **Close** to hide the Overlays dialog box.

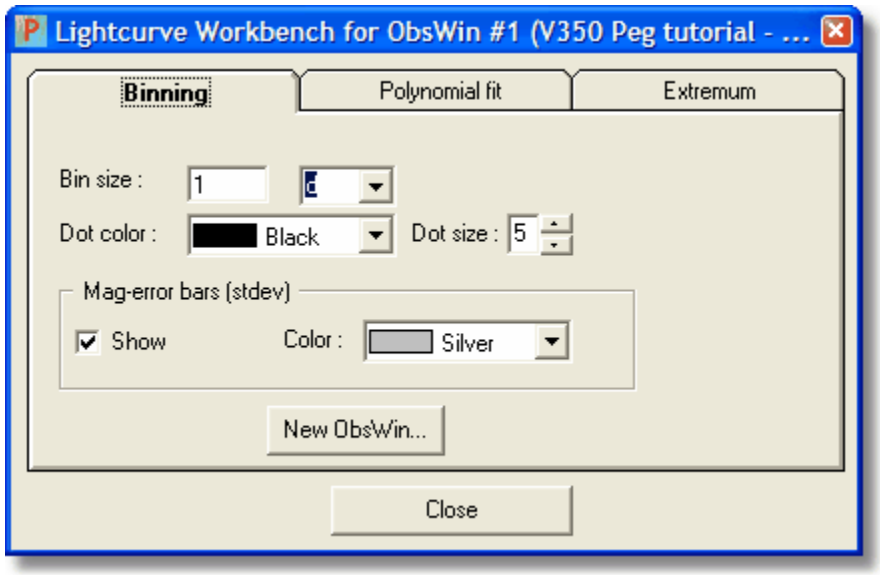


Example of an Overlays dialog box

12.2.5 Lightcurve Workbench...

The Lightcurve Workbench is a powerful *Peranso* tool for the advanced analysis of observations. It comprises functions for data reduction (binning), polynomial fitting and minimum/maximum (extremum) calculations.

The Lightcurve Workbench dialog box consists of 3 tabs : Binning, Polynomial fit and Extremum.



12.2.5.1 Binning

The binning tab is used to perform a data reduction on all observations in the Observations Window. Binning divides the observations into groups, referred to as bins. All observations belonging to a bin are averaged and represented by their average value (with standard deviation) in the newly created Observations Window.

The binning tab contains following elements :

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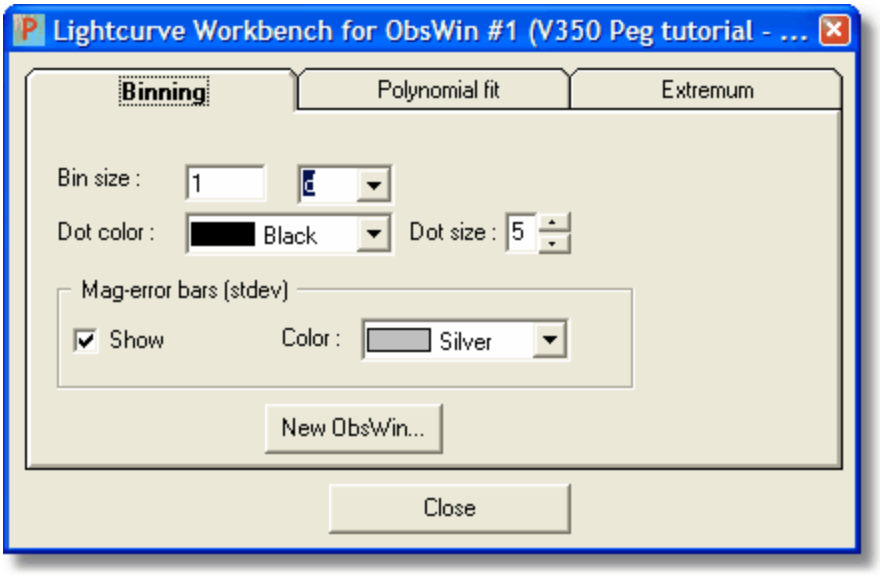

- **Bin size** : defines how the binning groups are created. One possibility is to express the bin size in sec(onds), min(utes), h(ours) or d(ays). E.g., when using a bin size value of 3 minutes, each binned observation will be the average value of all original observations contained within the same 3 minutes interval. Another possibility is to express the bin size in number of obs(ervations). E.g., when using a bin size of 10 observations, each binned observation will be the average value of 10 successive original observations.

- **Dot color** : defines the color in which binned observations will be drawn in the new Observations Window.

- **Dot size** : defines the size in pixels in which binned observations will be drawn in the new Observations Window.

- **Mag-error bars (stdev)** : each bin in the new Observations Window is the average value of one or more original observations. *Peranso* offers a possibility to complement the drawing of each binned observation with an Y error bar. This is a vertical line, drawn across the binned observation, that depicts the standard deviation of the bin, as calculated from the original observations. To draw the Y error bars, enable the **Show** option in the Mag-error bars frame. The color of the Y error bars is selected from the **Color** drop down menu.

- **New Obswin** : click on the **New ObsWin** button to create a new Observations Window that shows the binned representation of the original Observations Window.

An example of binning is shown in the figures below. The upper figure shows the original Observations Window, depicting a transit of *exoplanet TrES-1*, observed by Tonny Vanmunster on 2004, Sep 1-2. The lower figure shows the result of binning the original Observations Window, using a bin size of 3 minutes. The standard deviation of each bin is shown by vertical, silver colored lines.

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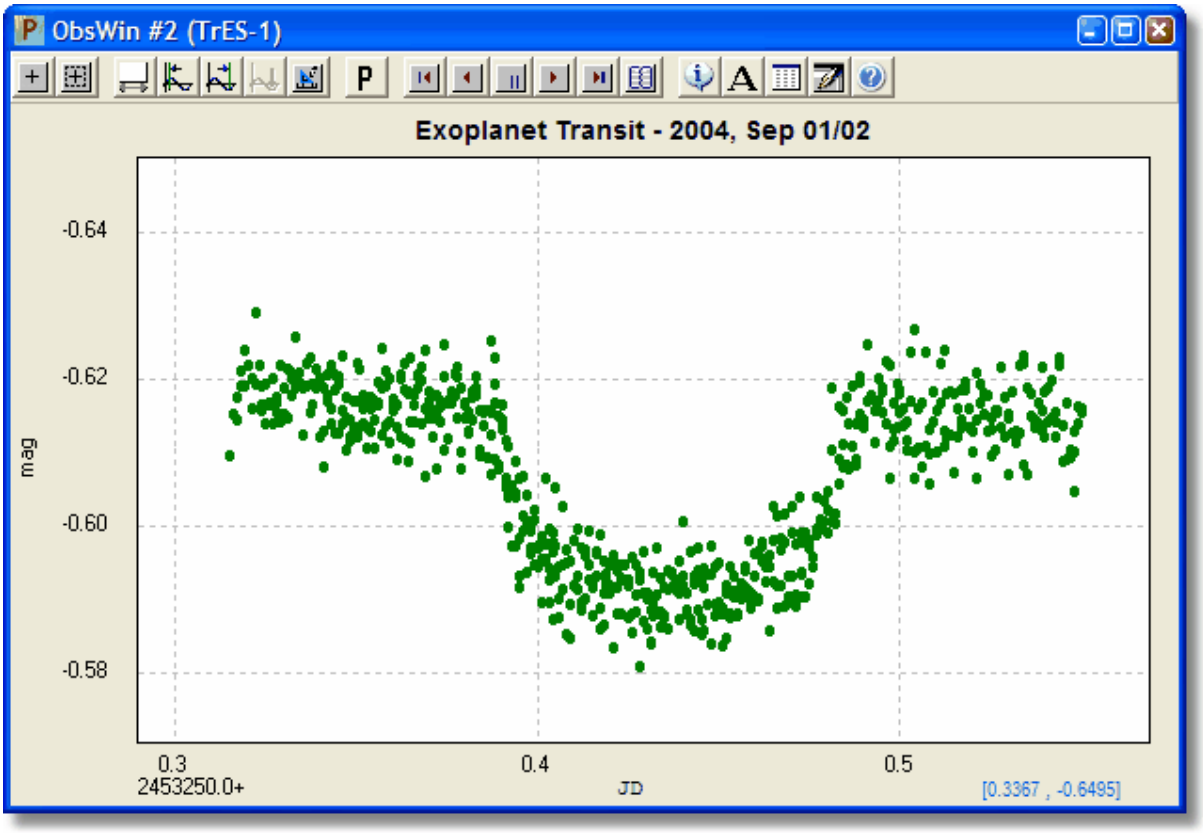

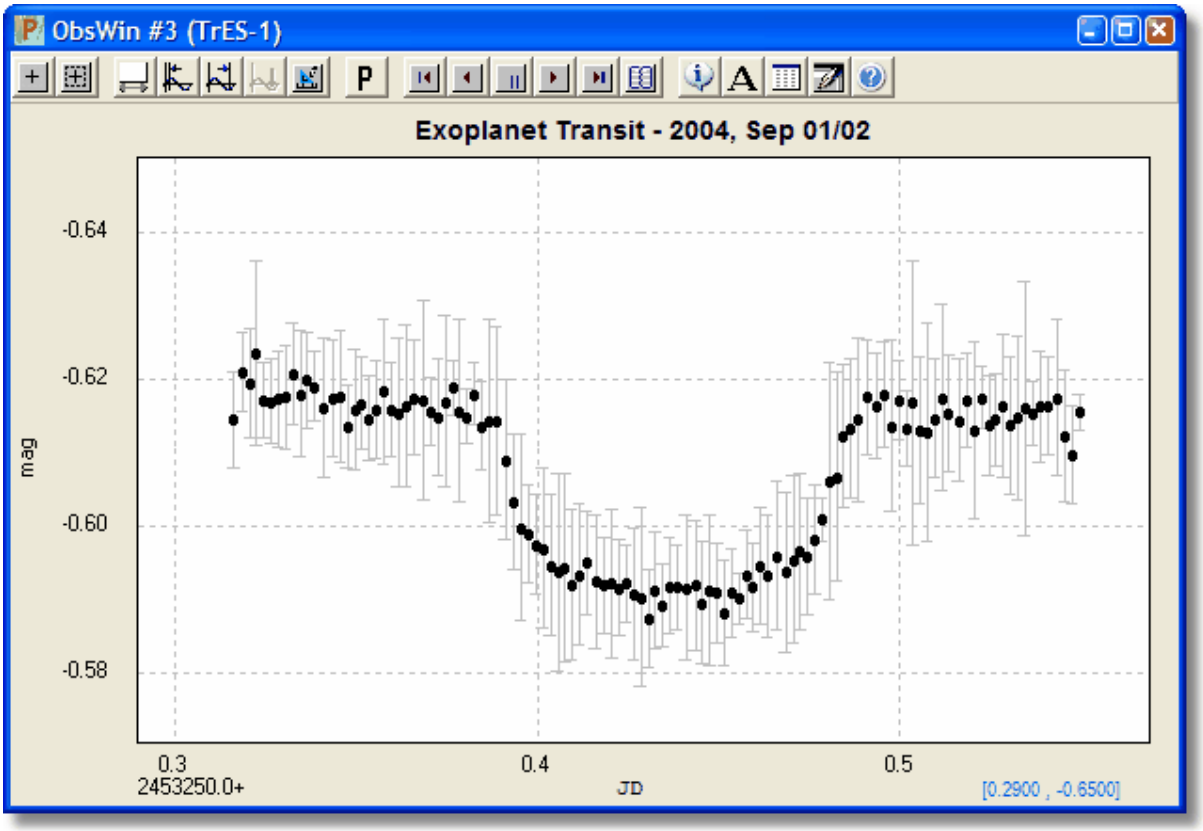

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12.2.5.2 Polynomial fit

A (univariate) polynomial is a mathematical expression involving a sum of powers in one variable, multiplied by coefficients. It is given by :

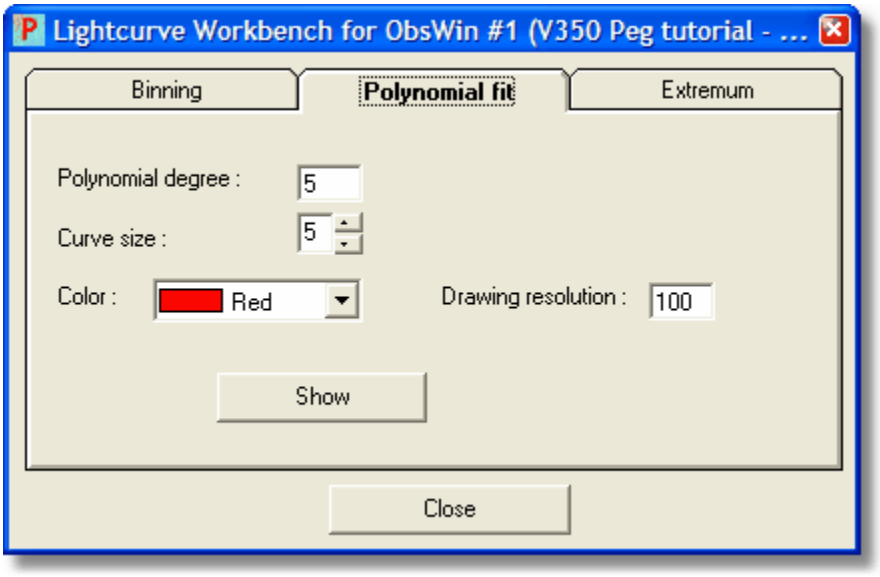
$$a_n x^n + \ldots + a_2 x^2 + a_1 x + a_0$$

where the *degree n* of the polynomial represents the number of terms in the expression.

Peranso implements a polynomial fitting routine that allows to fit (model) standard curves up to order 50. Evidently, variable star or asteroid light curves in most cases can not simply be described by polynomial equations. Therefore, the value of polynomial fitting is in determining the time of minimum or maximum light in a light curve segment, by fitting a polynomial to the observations (see Extremum).

The Polynomial fitting tab is used in *Peranso* to fit a polynomial through either all observations in the Observations Window, or through a selected segment. In the latter case, you first have to mark the segment by setting a Left and Right Margin Cursor.

The Polynomial fit tab contains following elements :



- **Polynomial degree** : indicates the degree or order of the polynomial to be drawn. Enter a value between 1 and 50. In most applications, a quadratic or fourth-order (4) polynomial is sufficient to determine a good model.
- **Curve size** : defines the width in pixels of the polynomial curve.
- **Color** : defines the color of the polynomial curve.
- **Drawing resolution** : determines the number of steps to be used for drawing the polynomial. It is just a visualization parameter and does not influence the internal accuracy of the polynomial calculation.

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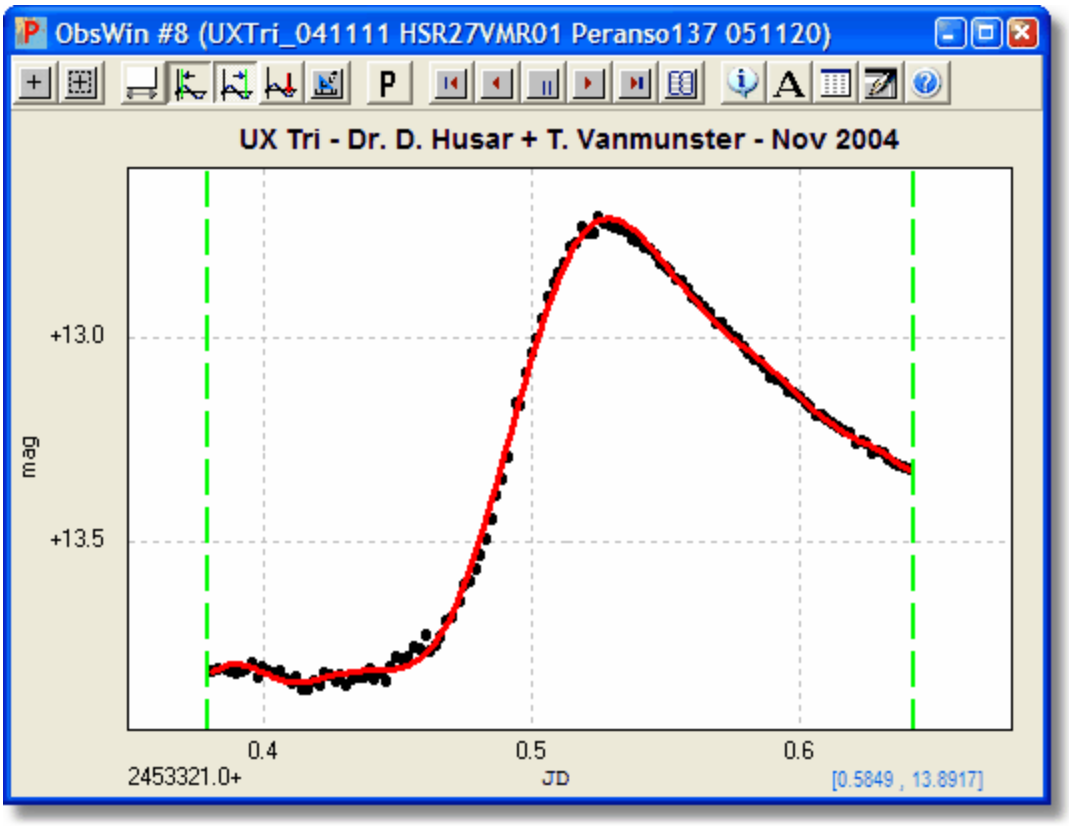
- **Show** : click this button to display the polynomial. If a Left and Right Margin cursor have been set, then the fitting will be limited to the indicated segment of the Observations Window. An Observations Window can have multiple Polynomials.

A polynomial is implemented in *Peranso* as an Overlay element. Each time you click the **Show** button to display a polynomial fit, a new overlay is created that contains the information related to that polynomial. Use the Overlays command to obtain an overview of all overlays of the current Observations Window. Other examples of Overlay types are : Left and Right Margin Cursors, Extremum indicators, a CLEANest Model Function, etc.

Overlays of an Observations Window are stored to and read from a *Peranso* file, similar to all other attributes of an Observations Window.

The figure below shows the result of a 12th degree polynomial fit to a light curve of the RRab-type variable star *UX Tri*. Observations by Dr. Dieter Husar (Hamburg, Germany) and Tonny Vanmunster (Landen, Belgium) on 2004, Nov 11/12.



12.2.5.3 Extremum

The Extremum tab is used to determine an extremum (minimum or maximum) of a polynomial, which gives a good approximation of the time of minimum or maximum light of the corresponding observations. The extremum is calculated by either using all observations in the Observations Window, or by restricting the calculation to a selected segment. In the latter case, you first have to mark the segment by setting a Left and Right Margin Cursor.

Peranso also offers the Kwee-van Woerden method to determine extrema.

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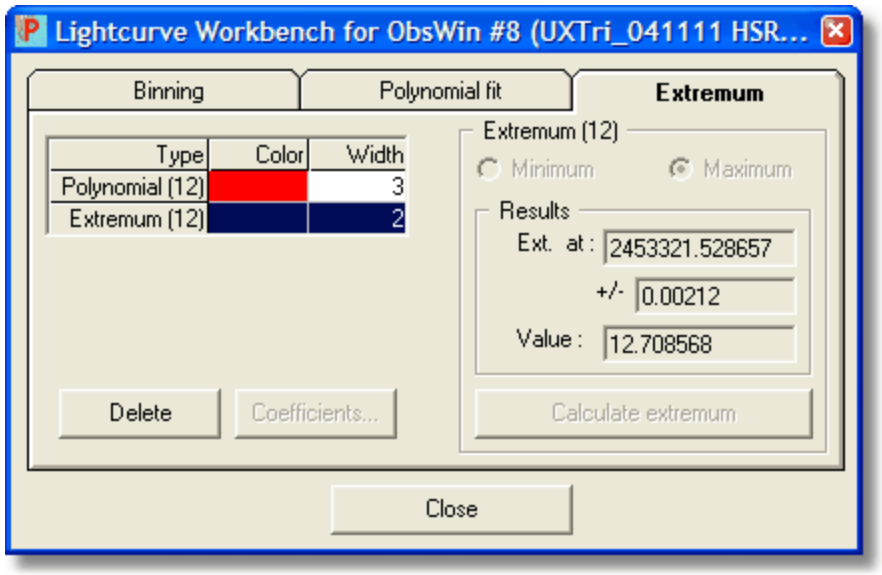
The Extremum tab comprises following elements :



- **Overlay list** : this tabular list at the left side of the tab shows all polynomials and extremum indicators of the current Observations Window. The type, color and line width of each is displayed. The type column furthermore tells the order of the polynomial or extremum. It is the value given between brackets.

  ⇨ To create a new extremum, select from the list the polynomial for which you want to calculate the extremum. Then select the extremum type (**Minimum** or **Maximum**) and click on **Calculate extremum** to start the calculation. The **Results** frame will show the time and magnitude values, corresponding to the extremum, as well as the uncertainty on the time value (indicated in the +/- field).

  ⇨ To look up an existing extremum, simply select the extremum from the list. The **Results** frame will show the time and magnitude values, corresponding to the extremum, as well as the uncertainty on the time value (indicated in the +/- field).

- **Minimum** : select this option if you want to find a minimum in the polynomial.

- **Maximum** : select this option if you want to find a maximum in the polynomial.

- **Calculate extremum** : click this button to determine the minimum or maximum and to graphically display the result by an extremum indicator. This is a vertical line, drawn in the same color as the polynomial.

- **Delete** : click this button to delete the selected overlays from the Overlay list.

- **Coefficients** : click this button to write to file the polynomial coefficients of the selected overlays in the Overlay list. You will be prompted to enter the file name.

An extremum indicator is implemented in *Peranso* as an Overlay element. Each time you click the **Calculate extremum** button to display an extremum indicator, a new overlay is created that contains the information related to that indicator. If an extremum indicator was already associated to the polynomial, then it is deleted before the new one is drawn. Use the Overlays command to obtain an

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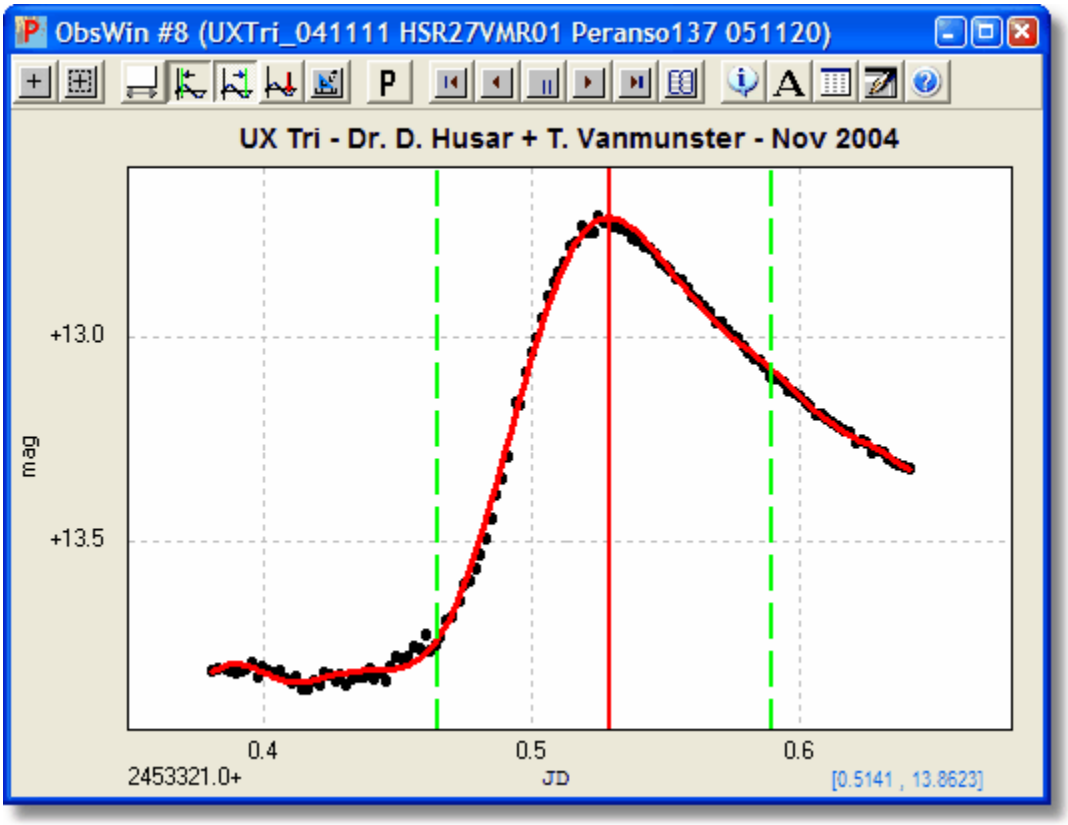
overview of all overlays of the current Observations Window.

The figure below shows the result of a 12th degree polynomial fit to a light curve of the RRab-type variable star *UX Tri*, after which an extremum (maximum) has been calculated. Observations by Dr. Dieter Husar (Hamburg, Germany) and Tonny Vanmunster (Landen, Belgium) on 2004, Nov 11/12.



12.2.6 Full View

Changes the X- and Y-axis limits (axes minimum and maximum values) such that all observation sets are displayed in the current Observations Window. Grid lines and axes annotation are drawn at ‘ easy-to-read’ values.

12.2.7 Copy Image to Clipboard

Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

12.2.8 Copy Data to Clipboard

Copies the attributes of each observation in the current Observations Window to the Microsoft Windows clipboard.

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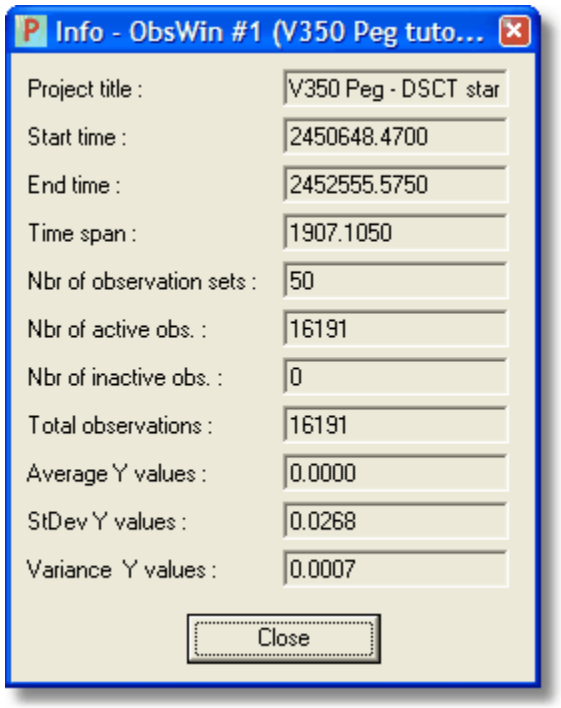
12.2.9 Export Data to File...

Saves the attributes of each observation in the current Observations Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

12.2.10 Info...

Displays the **Info** dialog box of the current Observations Window.



It contains following items :

- **Project title** : the title of the Observations Window.
- **Start time** : the time of the first observation in the Observations Window.
- **End time** : the time of the last observation in the Observations Window.
- **Time span** : the difference between End time and Start time.
- **Nbr of observation sets** : the number of observation sets in the Observations Window.
- **Nbr of active obs** : the number of active observations in the Observations Window.
- **Nbr of inactive obs** : the number of inactive observations in the Observations Window.
- **Total observations** : the amount of observations in the Observations Window.

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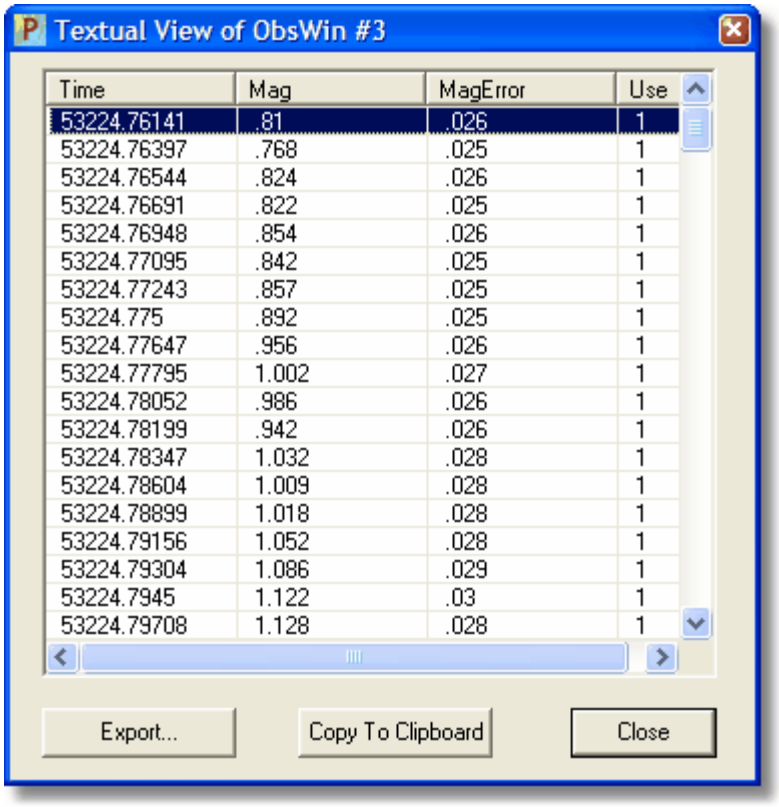
- **Average Y values** : the average y-value (mostly magnitude) of active observations in the Observations Window.
- **StDev Y values** : the standard deviation on the y-values of active observations in the Observations Window.
- **Variance Y values** : the variance on the y-values of active observations in the Observations Window.

12.2.11 Textual View...

Displays a **Textual View** of the Observations Window contents. It has as many columns as there are observation attributes in the Observations Window. Two columns are at least present in each Textual View : the Time and Magnitude of the observation. Other columns are optional. Below is an example Textual View form.



- Use the **Export** button to write the contents of the Textual View form to a file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.
- Use **Copy To Clipboard** to copy the contents of the Textual View form to the Microsoft Windows clipboard.
- Use **Close** to hide the form.

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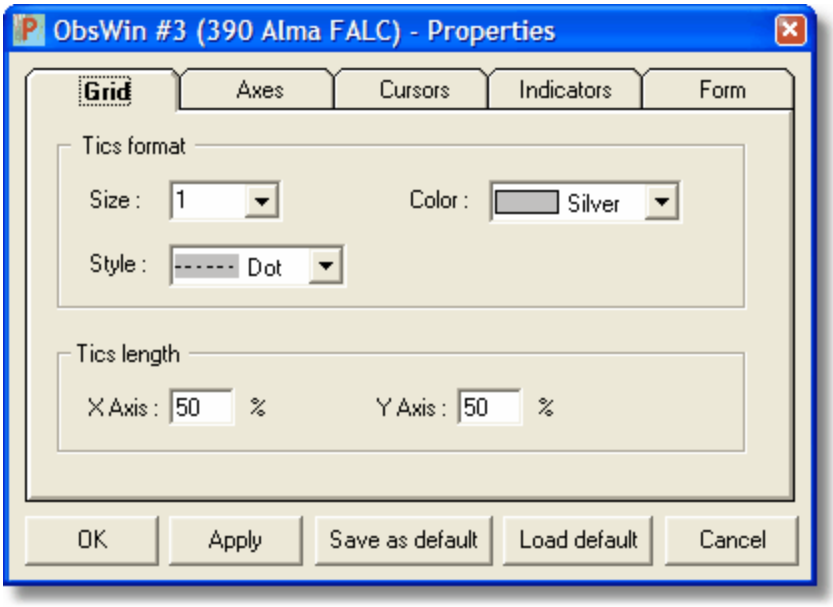
12.2.12 Properties...

Displays the **Properties** dialog box of the current Observations Window, which is used to modify the visual appearance of most elements of the Observations Window. It contains following tabs :

- **Grid**



This tab defines the visual appearance of the Observations Window's grid. It comprises :

⇨ **Tics format** : defines the line color, style and thickness of the grid lines (both X and Y axis).

⇨ **Tics length** : defines the length of the X axis and Y axis grid lines at both sides of the axis. Values should be between 0 and 50%. Default value is 50%, meaning that for both axes, the grid lines are drawn from one axis side to halfway the other axis side. Since this is done for both axis sides, the grid lines then span the full interior window height and width.

- **Axes**

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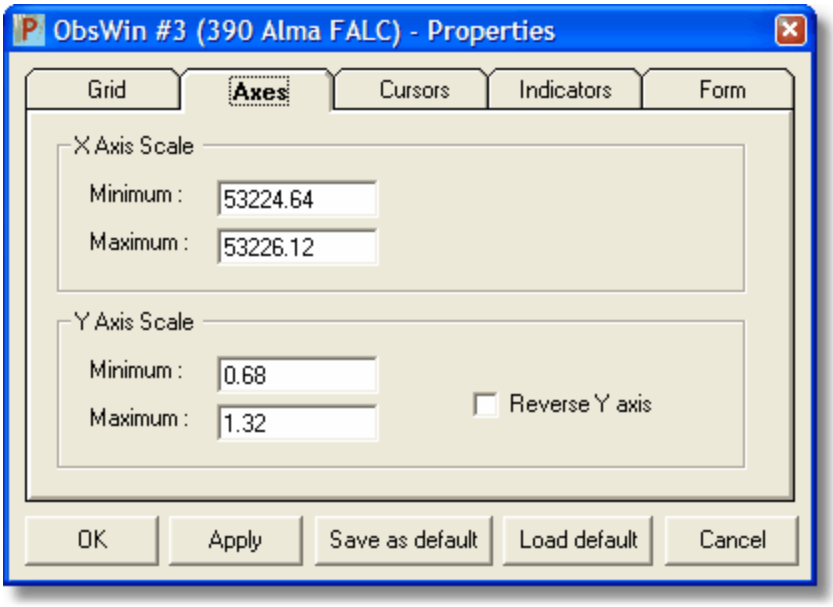
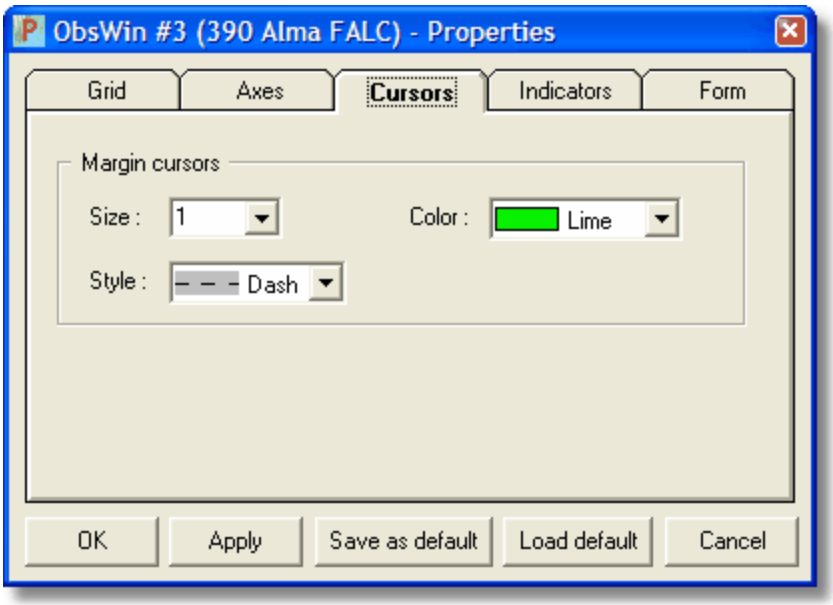


This tab defines the appearance of the Observations Window's axes. It comprises :

⇨ **X Axis Scale** : defines the minimum and maximum value to be used for drawing the X axis.

⇨ **Y Axis Scale** : defines the minimum and maximum value to be used for drawing the Y axis. In addition, it allows to reverse the Y Axis drawing.

- **Cursors**



This tab defines the line color, style and thickness of the Margin Cursors.

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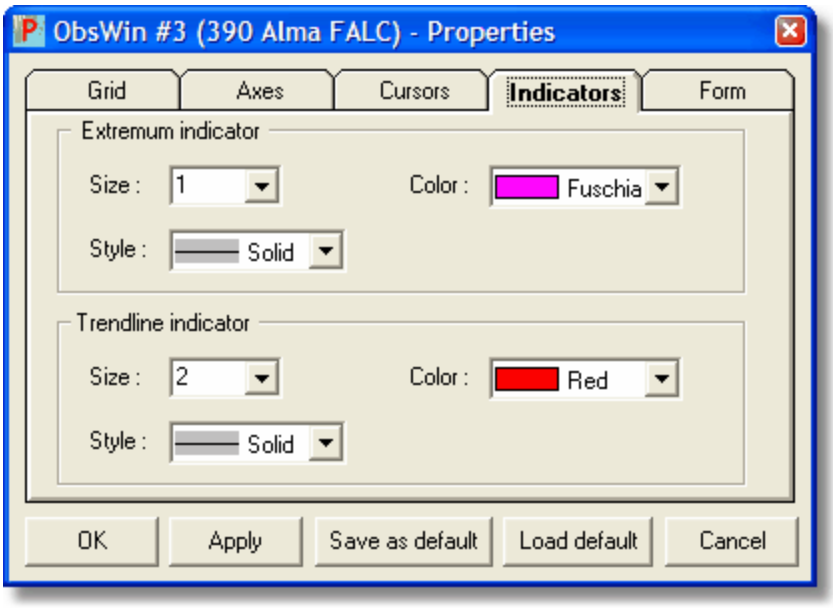
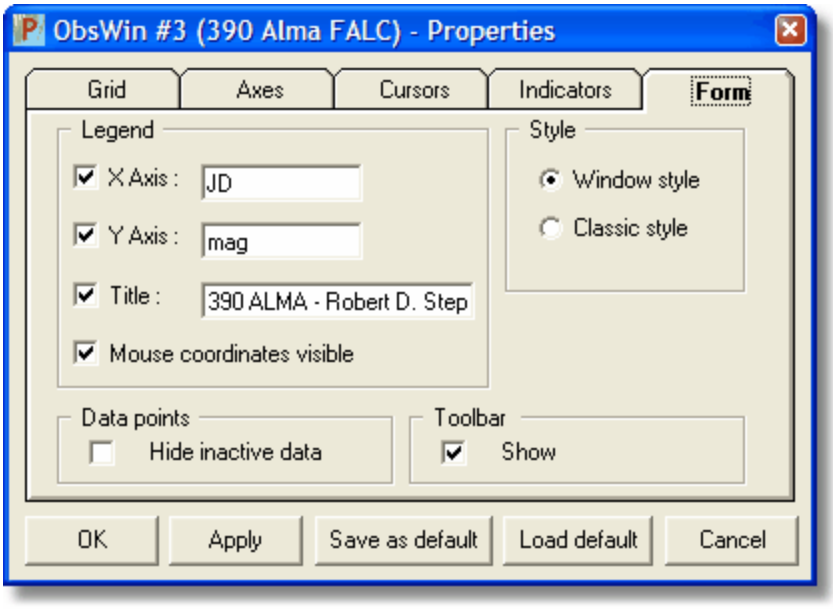
- **Indicators**



This tab defines the line color, style and thickness of the Extremum Indicator and of the Trendline Indicator.

- **Form**



This tab contains following elements :

⇨ **Legend** : defines the X Axis legend, Y Axis legend and title to appear in the Observations Window. Enter the legend in the text fields. To make the legend visible, click the check box in front of the legend. Use the **Mouse coordinates visible** check box to control the visibility of the mouse coordinates, that appear in the lower right corner of the Observations Window.

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⇨ **Style** : defines the appearance of the Observations Window. One can choose amongst a **Classic Style** (drawing most parts of the Observations Window in white color) and **Window Style** (drawing only the inner part of the Observations Window in white).

⇨ **Data points** : use the **Hide inactive data** check box to control visibility of the inactive data.

⇨ **Toolbar** : use the **Show** check box to control visibility of the Observations Window toolbar.

The Properties dialog box contains following buttons :

- **OK** : applies the selected Property values to the current Observations Window and closes the Property dialog box.
- **Apply** : applies the selected Property values to the current Observations Window, without closing the Property dialog box.
- **Save as default** : saves the current Property values (of all tabs) as default values, meaning that all newly created Observations Windows will employ these values.
- **Load default** : reads the default Property values and shows them in the Property dialog box. Use **Apply** or **OK** to subsequently apply the values to the current Observations Window.
- **Cancel** : closes the Property dialog box without modifying the Observations Window.

12.2.13 Close

Closes the current Observations Window. If unsaved data are present, the user will be asked for confirmation first.

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12.3 Period Analysis Menu

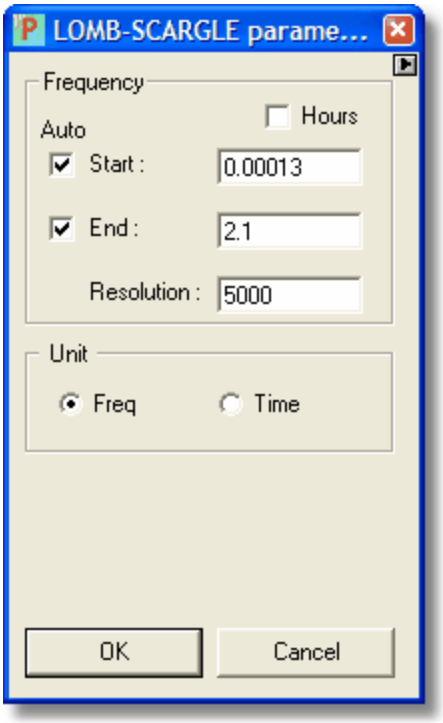
This menu groups commands to perform a period analysis on the current Observations Window. Several classification schemes exist to differentiate amongst period analysis methods.

12.3.1 Lomb-Scargle...

The Lomb-Scargle method transforms an (unequally-spaced) time series into a power spectrum, using a technique known as the Lomb periodogram. The method was derived by Lomb (1) in 1976, with improvements by Scargle (2) in 1982. Although the Lomb-Scargle periodogram decomposes the data into a series of sine and cosine functions, it is similar to least-squares 'statistical' methods (aiming at minimizing the difference between observed and modeled data).

Peranso uses the algorithm defined by Scargle, but optimized using the Horne and Baliunas method (3), which scales the periodogram by the total variance of the data, yielding a better estimation of the frequency of the periodic signal.

The Lomb-Scargle method is quite powerful for finding weak periodic signals.



The **Lomb-Scargle** dialog box contains following items :

- **Hours** : the default base time in *Peranso* is days, which is typical for variable star work. Asteroid period calculations are usually expressed in hours. You can select which base is used with the **Hours** toggle. Activating it will instruct *Peranso* to execute the subsequent period calculation in hours (or cycles per hour).

- Enter **Start** and **End** values to define the period scan range. Enter the **Resolution** value to define the period step size, i.e. :

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step size = (End - Start) / Resolution

Peranso proposes default values for the period scan range and resolution, based on the time span of the observations in the Observations Window. The **Resolution** value proposed by *Peranso* is small enough that you don`t waste CPU time, and big enough that you can be sure that you won`t miss any significant peak. Evidently, you may overwrite the values suggested by *Peranso*.

The **Auto** toggles are used to let *Peranso* suggest a **Start** and **End** value for the period analysis, based on the time span of the observations.

- The **Unit** frame allows to toggle between **freq**uency- or **time** domain based calculations.
- Click **OK** to start the calculation, **Cancel** to quit the operation. When the calculation is started, a new Period Window is created to show the results of the period analysis calculation. During the calculations, a progress indicator dialog box is displayed. Click the **Cancel** button to stop the calculation. Prominent periods of the Period Window appear as peaks.

(1) Lomb, N.R., 1976, Ap&SS, 39, 447
(2) Scargle, J.D., 1982, Ap.J., 263, 835
(3) Horne, J.H., Baliunas, S.L., 1986, ApJ, 302, 757

12.3.2 Bloomfield...

The Bloomfield (1) method is quite similar to the Lomb-Scargle method, and also calculates a power spectrum, starting from unequally-spaced data, using the *Least Squares Standard Technique*.

The **Bloomfield** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as peaks.

(1) Bloomfield, P., 1976, Fourier Analysis of Time Series: An Introduction, Wiley, New York.

12.3.3 DFT (Deeming)...

In 1975, Deeming (1) demonstrated that it is possible to use the Discrete Fourier transform (DFT) for the Fourier and power spectrum analysis of unequally-spaced data, with results that are comparable to analysis with equally-spaced data.

Peranso implements the algorithm presented by Deeming in the afore mentioned publication.

The **DFT** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as peaks.

(1) Deeming, T.J., 1975, Ap&SS, 36, 137

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12.3.4 DCDFT (Ferraz-Mello)...

This method calculates the power spectrum of unequally-spaced data using a so called 'date compensated' discrete Fourier transform. This transform is defined so as to include the uneven spacing of the dates of observation and weighting of the corresponding data. The method is useful when the signal-to-noise ratio of the data is low, and for low frequency data.

Peranso implements the algorithm a described by Ferraz-Mello (1).

The **DCDFT** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as peaks.

(1) Ferraz-Mello, S., 1981, Astron. J., 86(4)

12.3.5 CLEANest (Foster)...

The CLEANest and SLICK methods calculate the power spectrum of unequally-spaced data using an advanced implementation of the Date Compensated Discrete Fourier Transform (DCDFT). CLEANest is a particularly effective technique for detecting and describing multi periodic signals.

Peranso implements the CLEANest algorithm as described by Grant Foster (1). In addition, *Peranso* implements the SLICK method (1), which is a very useful tool for extracting multiple signal components from a given data set. SLICK iteratively searches for multiple frequencies in a given signal, and attempts to find a "best-fitting ensemble" of frequencies. SLICK will adjust each "found" frequency such that overall signal strength is maximized. Both methods are combined in one convenient *Peranso* dialog box, called the CLEANest Workbench.

A CLEANest calculation is started from the **CLEANest** Period Determination dialog box, which is similar to the Lomb-Scargle dialog box. Subsequent refinements can be made iteratively using the CLEANest Workbench. Prominent periods of the Period Window appear as peaks.

Remark

The CLEANest spectrum is not truly a spectrum, but a composite graphical representation of two sets of information : (a) the optimal discrete Fourier representation of the data (the so called *discrete spectrum*), and (b) the Fourier transform of the residuals (the so called *residual spectrum*).
The discrete spectrum is formed by the individual amplitudes of each frequency component that is used to construct the CLEANest *model function*. They are represented by horizontal lines in the spectrum, drawn at the identified frequencies, and have no width (only an amplitude).
The residual spectrum is obtained by subtracting the model function from the original data and Fourier analyzing the residuals by a DCDFT.

(1) Foster, G., 1995, Astron. J., 109, 1889

12.3.6 FALC (Harris)...

Dr. Alan Harris' (JPL) famous Fourier Analysis method, *FALC*, is a de facto standard for asteroid light curve period analysis (1). Dr. Harris is one of the most recognized leaders in asteroid research. He developed a program called *Fourier Analysis of Light Curves FALC*, that takes multiple light curve segments (ObsSets) and performs a Fourier analysis on the data. For each light curve segment, a new magnitude level (zero-point) is assumed. It is also possible to do a linear least squares fit for a

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specified period up to any harmonic order.

Dr. Harris' method is fully integrated in *Peranso*, through the **FALC** Period Determination dialog box, which is described in Tutorial 6. In addition, *Peranso* provides a FALC (Harris) Workbench, that presents Dr. Harris' method in a convenient graphical user interface (GUI). This GUI is extremely useful for asteroid enthusiasts, and mimics FALCs original approach in a Windows environment. The FALC Workbench also provides sophisticated outputs, showing f.i. the uncertainty of the fitted curve. In addition, it allows to keep a period constant and increment harmonic orders, to determine the most significant fit order to work with.

Dr. Harris' method is very interesting too for variable star light curve analysis, as it effectively takes into account magnitude error values in the period determination. It currently is the only method in *Peranso* that uses the error bar (sigma) of magnitudes.

A full introduction to the **FALC** method is provided in Tutorial 6. Prominent periods of the Period Window appear as valleys.

(1) Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H.J., Debehogne, H., Zeigler, K.: 1989, Icarus 77, 171-186.

12.3.7 ANOVA...

This method employs periodic orthogonal polynomials to fit observations, and the analysis of variance (ANOVA) statistic to evaluate the quality of the fit. This method was proposed by Schwarzenberg-Czerny (1). It strongly improves peak detection sensitivity and damps alias periods.

Peranso implements the algorithm a described by Schwarzenberg-Czerny (1).

The **ANOVA** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as peaks.

(1) Schwarzenberg-Czerny, A., ApJ, 460, L107-110, 1996

12.3.8 Jurkewich...

The Jurkewich method is a statistical period analysis method, proposed in 1971, and also operating on unequally-spaced data.

Peranso implements an algorithm that is slightly different from the one proposed by Jurkewich, following modifications by Dupuy and Morris [1985], and Gaspani (1) [1991].

The **Jurkewich** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as peaks.

(1) http://www.la-grange.net/astro/VR/gaspani/jurk.for

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12.3.9 Dworetsky...

The Dworetsky (1) string method for period analysis is an intuitively simple method. The observation data are folded on a series of trial periods and at each period the sum of the lengths of line segments joining successive points (the string-length) is calculated. Minima in a plot of string-length versus trial frequency indicate possible periods. The string-length method is especially useful if a very small number of randomly spaced observations are used.

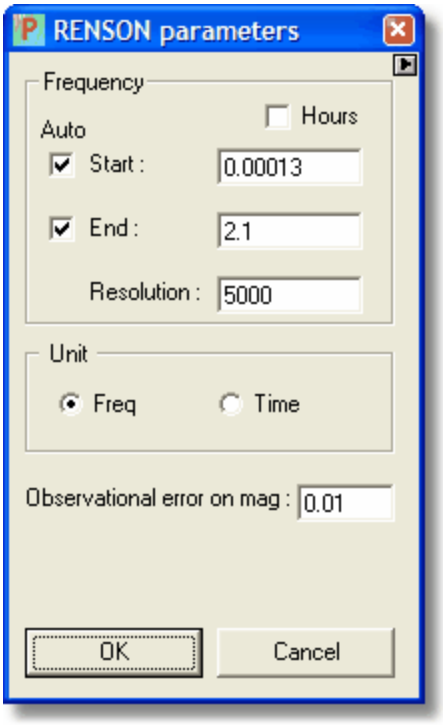
The **Dworetsky** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as valleys.

(1) Dworetsky, M.M., 1983, Mon. Not. R. Astron. Soc., 203, 917

12.3.10 Renson...

Renson (1) also developed a string method for period analysis, but his method proposes a better distribution of the trial periods, by taking into account the observational error, for determining a criterium to select the right period. The advantage of the method is most obvious when the amount of observations is very low.

The **Renson** dialog box is similar to the Lomb-Scargle dialog box, except for the presence of the **Observational error on mag** field, which allows to input the observational error to be used by the Renson method. Prominent periods of the Period Window appear as valleys.



(1) Renson, P., 1978, A&A., 63, 125

12.3.11 PDM...

The phase dispersion minimization (PDM) technique was described in detail by Stellingwerf (1) and is very well suited to search for periodicities if only a few observations are available over a limited period of time, and especially if the light curve is highly non-sinusoidal.

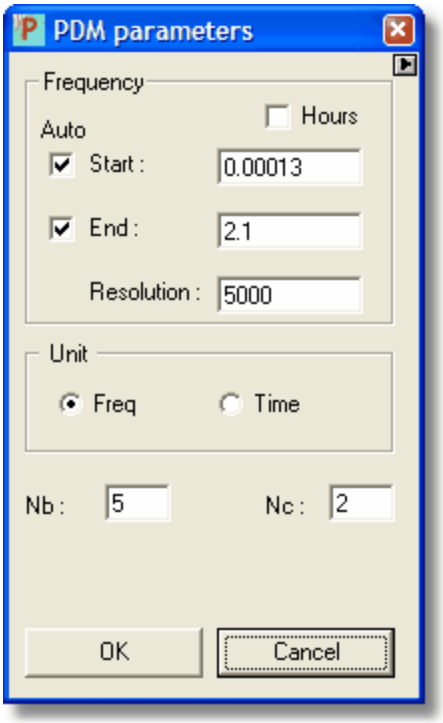
PDM first folds the observation data on a series of trial frequencies. For each trial frequency, the full phase interval (0,1) is divided into a user defined number of bins. The width of each bin is also defined by the user, such that (a) either an observation point is not picked (if a bin width is selected that is narrower than the bin spacing), (b) or an observation point can belong to more than one bin (if a bin width is selected that is wider than the bin spacing).

The variance of each of these bins is then calculated, giving a measure of the scatter around the mean light curve, defined by the means of the data in each sample. The PDM statistic then is calculated by dividing the overall variance of all the samples by the variance of the original (unbinned) dataset. This process is repeated for each next trial frequency.

Note that if the trial period is not a true period, the PDM statistic will be approximately equal to 1. If the trial period is a "true" period, the PDM statistic will reach a local minimum and should be close(r) to 0.

The **PDM** dialog box is shown below. It is similar to the Lomb-Scargle dialog box, but allows to enter **Nb** (number of bins) and **Nc** (so called "covers" of Nb bins). A very good general scheme is to use Nb = 5 and Nc = 2 for a rough scan of the data. Later on, a finer bin structure should be used to obtain an accurate period.

Prominent periods of the Period Window appear as valleys.



(1) Stellingwerf, R.F., 1978, Astroph. J., 224, 953

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12.3.12 Lafler-Kinman...

Lafler-Kinman (1) is an effective method to analyze *Cepheids* or *RR Lyrae* time series in search for periodic signals. It is a string-length method : it folds the observation data on a series of trial periods, and at each trial period it calculates the sum of the lengths of line segments joining successive points (the string-length). Minima in the plot of string-length versus trial frequency (Period Window) indicate possible periods.

The **Lafler-Kinman** dialog box is similar to the Lomb-Scargle dialog box. Prominent periods of the Period Window appear as valleys.

(1) Lafler J., Kinman T.D., An RR Lyrae Star Survey with the Lick 20-INCH Astrograph II. The Calculation of RR Lyrae Periods by Electronic Computer, Astrophysical Journal Supplement, vol 11, p. 216, 1965.

12.3.13 EEBLS (exoplanet transits)...

Box-fitting Least Squares (BLS) algorithms (1) are particularly effective to analyze stellar photometric time series in search for periodic transits by *exoplanets*. They search for signals characterized by a periodic alternation between two discrete levels, with much less time spent at the lower level. EEBLS (*Edge Enhanced Box-fitting Least Squares*) is an extension to BLS, that takes into account edge effects during exoplanet transits, as suggested by *Dr. Peter McCullough* (STScI).

Peranso allows calculating and visualizing the EEBLS frequency spectrum, folding of the time series over the most dominant EEBLS period, calculating the epoch of mid-transit events, the transit depth and duration, etc. In addition, *Peranso* graphically displays the fit obtained by the EEBLS method.

A full introduction to the **EEBLS** method is provided in Tutorial 4. Prominent periods of the Period Window appear as peaks.

(1) Kovacs G., Zucker S., Mazeh T., *A box-fitting algorithm in the search for periodic transits*, A&A, 2002.

12.3.14 Spectral Window...

Suppose one observes a constant star each night at exactly the same time (i.e., a 1 day period), then the data analysis should display a period with a peak at 1 day. This is logical, as the peak is a direct result of the sampling frequency itself. The period is not the true period, but results from observing a (constant) object at exactly the same moment in time. See also Aliasing.

The **Spectral Window** in *Peranso* calculates the pattern caused by the structure of gaps in the observations. It is not a true Fourier spectrum for a star, but indicates what peaks in a Period Window are artifacts of your sampling. It is typically used in combination with any of the above period analysis methods, and is calculated to demonstrate that the period found by one of the above methods can not be the result of the data sampling.

Tutorial 1 presents an example.

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12.4 Tools Menu

12.4.1 Julian Day Calculator...

This command is identical to the Peranso Desktop Window Julian Day Calculator command.

12.4.2 Exoplanet Diagnostic (Tingley)...

This command is identical to the Peranso Desktop Window Exoplanet Diagnostic (Tingley) command.

12.4.3 EASolver (Wils)...

A full description of the **EASolver (Wils)** method is provided in Tutorial 5.

12.4.4 FALC (Harris) Workbench...

A full description of the **FALC (Harris) Workbench** is provided in Tutorial 6.

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12.5 Window Menu

12.5.1 Close All Period Windows

Closes all Period Windows associated with the current Observations Window.

12.5.2 Close All Phase Windows

Closes all Phase Windows associated with the current Observations Window.

12.5.3 Close All Windows

Closes all *Peranso* windows. If a window contains unsaved data, the user will first be presented a possibility to Save the window contents.

12.5.4 Tile Horizontally

Organizes all non-minimized *Peranso* windows (including open dialog boxes) to take advantage of the available *Peranso* Desktop, by laying out these windows horizontally across the Desktop.

12.5.5 Tile Vertically

Organizes all non-minimized *Peranso* windows (including open dialog boxes) to take advantage of the available *Peranso* Desktop, by laying out these windows vertically across the Desktop.

12.5.6 Cascade

Stacks all non-minimized *Peranso* windows (including open dialog boxes) starting at the top left corner of the *Peranso* Desktop.

12.5.7 Arrange Icons

Peranso windows can be minimized, at which point they become small bars (icons). If these have become scattered about the *Peranso* Desktop, the **Arrange Icons** command will stack them neatly at the bottom of the Desktop.

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12.6 Help Menu

This menu is identical to the Peranso Desktop Window Help menu.

12.7 Toolbar

The Observations Window Toolbar groups following commands :

Icon	Command
	Add Observation Set
	Add Multiple Observation Sets
	Full View
	Set/unset Left Margin Cursor
	Set/unset Right Margin Cursor
	Find Extremum
	Period Determination
	Zoom on First Obsset
	Zoom on Previous ObsSet
	Zoom on Active ObsSet
	Zoom on Next ObsSet

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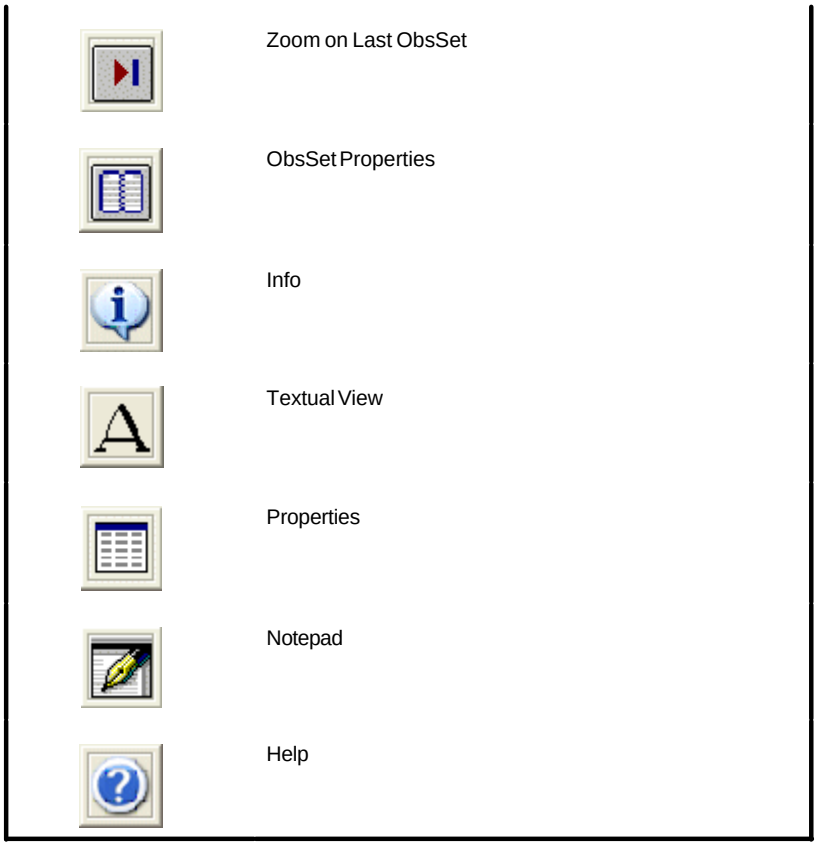

12.7.1 Find Extremum

Calculates an extremum (minimum or maximum) in the data represented in the current *Peranso* window. This toolbar button becomes active only if both the left and right Margin Cursors have been defined (set), to determine the interval in which to look for an extremum. *Peranso* uses the Kwee-van Woerden method to calculate the extremum. In addition, *Peranso* offers an extremum method based on polynomial fitting.

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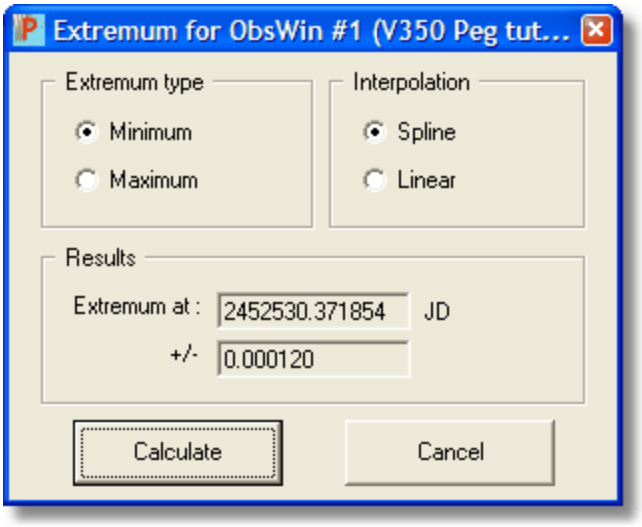

The **Extremum** dialog box contains following items :

- **Extremum type** : select either **Minimum** or **Maximum** to indicate the kind of extremum you want to calculate
- **Interpolation** : select the Kwee-van Woerden interpolation method. Data are interpolated either using a **linear** interpolation method or a **spline** (2) interpolation method.
- **Results** : click the **Calculate** button to start the extremum calculation. The calculated extremum is displayed in the **Extremum at** field, together with the extremum error, which is displayed in the ***+/-*** field. The extremum is graphically indicated in the current *Peranso* window using an Extremum Indicator. An error or warning message will appear if insufficient data are included in the interval marked by the Margin Cursors, or if no extremum could be determined.
- **Cancel** : quits the extremum calculation and removes the Extremum Indicator.

Remark

The Kwee-van Woerden method assumes a symmetrical light curve and therefore is very well suited for finding extrema in eclipsing binaries. The method works best if the search interval consists of points that are relatively close to the extremum.

Note that the calculated Kwee-van Woerden error almost always is smaller than in extremum calculations with other methods. It reflects the assumption of a perfect symmetrical light curve. In our experience, the Kwee-van Woerden error values seem to be over-optimistic on most data sets we have analysed, although consistent with values reported by other software implementations of the Kwee-van Woerden method.

(1) Kwee, K., van Woerden, H., 1956, Bulletin of the Astronomical Institutes of the Netherlands BAN, Vol XII, 464.
(2) Based on Forsythe, Malcom, Moler, Computer methods for mathematical computations, Prentice-Hall Inc., 1977.

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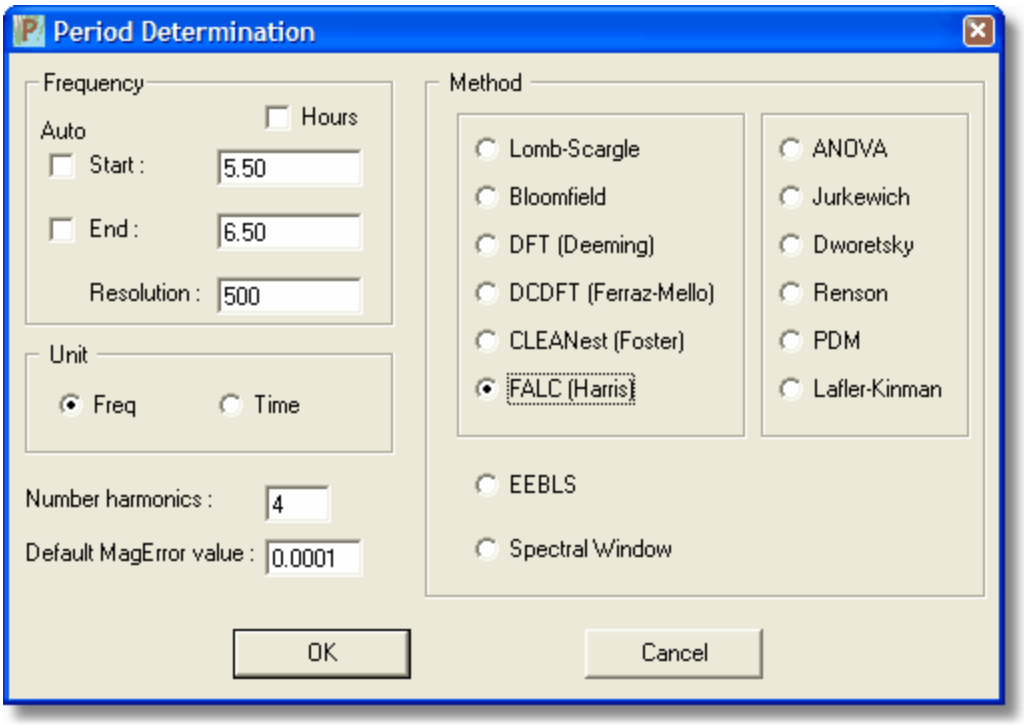
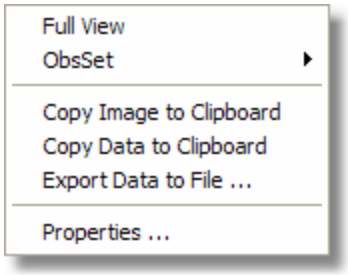
12.7.2 Period Determination

The **Period Determination** dialog box groups all period analysis methods, accessible through the Period Analysis Menu, in one convenient dialog box. First select a period analysis **Method** at the right side of the dialog box, then follow the instructions for that period analysis method from the corresponding Period Analysis Menu entry. Click **OK** to start the period determination, and **Cancel** to quit.



12.8 Observations Window Context Menu

Click the right mouse button to pop up the Observations Window Context Menu, while the mouse cursor is anywhere inside the ObsWin.



- **Full View**

  Changes the X- and Y-axis limits (axes minimum and maximum values) such that all observation sets are displayed in the current Observations Window. Grid lines and axes annotation are drawn

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at ‘easy-to-read’ values.

- **ObsSet**

  Pops up the ObsSet Context Menu, showing commands that will execute on the currently active ObsSet.

- **Copy Image to Clipboard**

  Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

- **Copy Data to Clipboard**

  Copies the attributes of each observation in the current Observations Window to the Microsoft Windows clipboard.

- **Export Data to File**

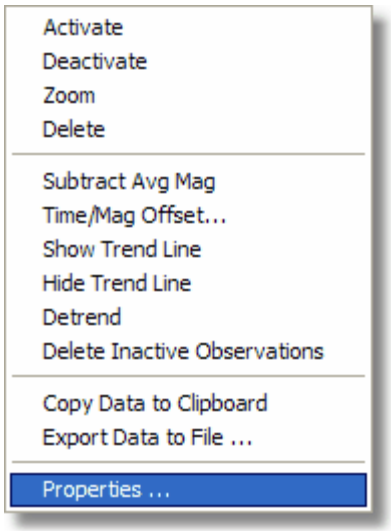
  Saves the attributes of each observation in the current Observations Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

- **Properties**

  Displays the Properties dialog box of the current Observations Window.

12.8.1 ObsSet Context Menu

The **ObsSet** Context Menu displays a number of commands that execute on the currently active ObsSet.



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- **Activate**

  Makes all observations of the current ObsSet active, meaning they will be included in all *Peranso* analysis commands.

- **Deactivate**

  Makes all observations of the current ObsSet inactive, meaning they will be excluded from all *Peranso* analysis commands.

- **Zoom**

  Zooms in on the current ObsSet to make the observations nicely fit in the Observations Window. To again display all observation sets, use the Full View command.

- **Delete**

  Deletes the current ObsSet. This operation can not be undone.

- **Subtract Avg Mag**

  The alignment of Observation Sets often is critical to finding the right period, since a period determination method can find a different dominant period for different ObsSet alignments. In many cases, you will have to adjust ObsSets so that they mesh well together, before you start the period analysis. The alignment is not always mandatory, and very much depends on the particular characteristics of the observations (e.g., usage of filters, similarities between observing instruments, evolution of light curve over time, etc.).

  By adjusting an ObsSet, you move it up or down in relation to the other ObsSets in the ObsWin. By doing this, you can get the data for a given ObsSet to line up with the data from other ObsSets. In some cases (for instance, when working with unfiltered differential variable star magnitudes obtained by different observers) this is not very easy. *Peranso* offers two ways of adjusting ObsSets : the Time/Mag Offset command and the Subtract Avg Mag command.

  The **Subtract Avg Mag** command instructs *Peranso* to calculate the average magnitude of the active ObsSet, and to subtract this average magnitude value from each observation in the ObsSet. You may also apply a Subtract Avg Mag to all Observation Sets of an ObsWin at once, by using the Subtract Avg Mag All command.

- **Time/Mag Offset**

  The **Time/Mag Offset** command is used to apply a time or magnitude offset (displacement) to the active ObsSet. Enter the **Time offset** and **Magnitude offset** values in the text boxes, and then click **Apply**. In most cases, you will leave the **Time offset** value to 0, and you will only adjust the magnitude values of the ObsSet.

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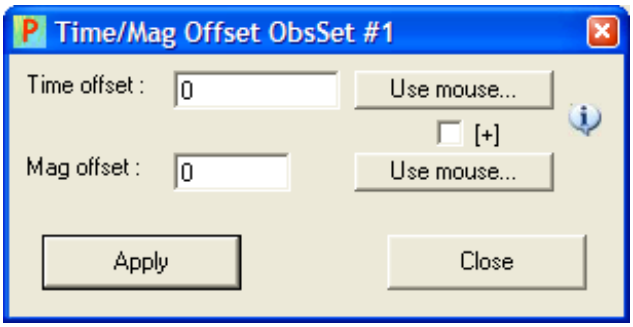

You may also determine the offset values graphically using the mouse, by indicating the start and end positions in the Observations Window. The distance between the start and end positions determines the offset values.

⇨ To determine the **Time offset** value in a graphical way, click the **Use mouse** button to the right of the **Time offset** text box. The mouse cursor changes in , to indicate that you have to select the start position for the displacement calculation in the Observations Window. When done, the mouse cursor changes in . Select the end position in the Observations Window. The **Time offset** text field will now display the abscissa distance between the start and end positions.

⇨ The **Mag offset** value can be determined in a similar way. Click the **Use mouse** button to the right of the **Mag offset** text box.

To graphically determine both the Time and Mag offset values in one step, click the **[+]** button first, then click either of the **Use mouse** buttons, and select the start and end positions as above.

You may also apply a Time or Mag Offset to all Observation Sets of an ObsWin at once, by using the Time/Mag Offset All command.

- **Show Trend Line**

  Fits a line through all observations of the active ObsSet, using the least squares method. The color, size and style of the trendline can be defined using the Properties dialog box.

  You may also apply a Show Trend Line to all Observation Sets of an ObsWin at once, by using the Show Trend Line All command.

- **Hide Trend Line**

  Hides the trend line in the active ObsSet, calculated by the **Show Trend Line** command.

  You may also apply a Hide Trend Line to all Observation Sets of an ObsWin at once, by using the Hide Trend Line All command.

- **Detrend**

  Calculates the linear trend of all observations in the active ObsSet, using the least squares method, and subtracts it from the observations.

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You may also apply Detrend to all Observation Sets of an ObsWin at once, by using the Detrend All command.

- **Delete Inactive Observations**

  Deletes all inactive observations in the active ObsSet.

  You may also apply Delete Inactive Observations to all Observation Sets of an ObsWin at once, by using the Delete Inactive Observations All command.

- **Copy Data to Clipboard**

  Copies the attributes of each observation in the active ObsSet to the Microsoft Windows clipboard.

- **Export Data to File**

  Saves the attributes of each observation in the active ObsSet to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

- **Properties**

  Displays the ObsSet Properties dialog box.

12.8.1.1 ObsSet Properties

Display the **Properties** dialog box for the active ObsSet and allows to modify certain attributes of the ObsSet. It contains two tabs :

- **Edit fields**

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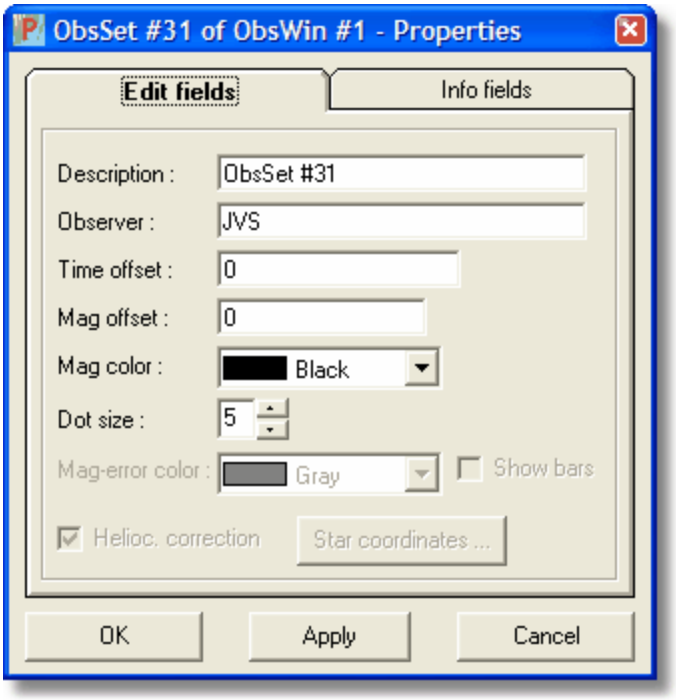

This tab displays ObsSet attributes that can be changed by the user. It comprises :

⇨ **Description** : describes (in free format) the observation set.

⇨ **Observer** : defines the name of the observer(s).

⇨ **Time offset** : defines a constant time correction to be applied to the time values of the ObsSet observations. Click **Apply** to apply the correction.

⇨ **Mag offset** : defines a constant magnitude correction to be applied to the magnitude values of the ObsSet observations. Click **Apply** to apply the correction.

⇨ **Mag color** : a drop down menu with a set of 15 predefined colors. The selected color is used to draw the observations.

⇨ **Dot size** : an up-down field with 5 predefined values. The selected value defines the thickness of the observation circles, drawn in the Observations Window.

⇨ **Mag-error color** : this field is only active if the ObsSet contains observations with Magnitude Error values. It is a drop down menu with a set of 15 predefined colors. The selected color is used to draw the magnitude error bars.

⇨ **Show bars** : this field is only active if the ObsSet contains observations with Magnitude Error values. If enabled, then the ObsSet will be drawn with magnitude error bars.

⇨ **Helioc. correction** : allows to apply a heliocentric time correction to all observations in the ObsSet. First enter the coordinates of the corresponding object by clicking the Star coordinates button. Once done, the **Helioc. correction** check box becomes selected. Click **Apply** to apply the heliocentric correction.
If the observations in the ObsSet have already been heliocentric corrected before, the toggle will be enabled, but can not be selected.

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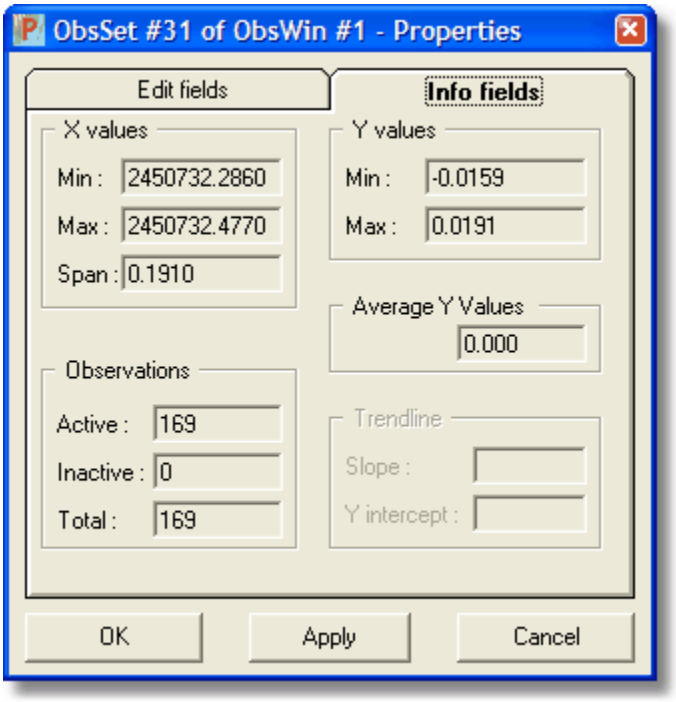
- **Info fields**



This tab displays ObsSet attributes that can not be modified by the user. It simply provides relevant information about the active ObsSet, and comprises :

⇨ **X values** : the minimum and maximum abscissa values of the active ObsSet, the corresponding time span.

⇨ **Y values** : the minimum and maximum ordinate values (mag).

⇨ **Observations** : the amount of active and inactive observations in the ObsSet, as well as the total amount of observations.

⇨ **Average Y Values** : the average ordinate value.

⇨ **Trendline** : the slope and Y intercept values of the Trendline indicator, if present.

- **OK** : applies the changes made in the **Edit fields** tab to the active ObsSet. This closes the dialog box.
- **Apply** : applies the changes made in the **Edit fields** tab to the active ObsSet.
- **Cancel** : closes the dialog box, without changing the active ObsSet.

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Part

13 The Period Window

13.1 File Menu

This menu is identical to the Observations Window File Menu.

13.2 Period Window Menu

13.2.1 Full View

Changes the X- and Y-axis limits (axes minimum and maximum values) such that all data are displayed in the current Period Window. Grid lines and axes annotation are drawn at ‘easy-to-read’ values.

13.2.2 Copy Image to Clipboard

Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

13.2.3 Copy Data to Clipboard

Copies the X axis (time or frequency) and Y axis (theta) values of the current Period Window to the Microsoft Windows Clipboard.

13.2.4 Export Data to File

Saves the X axis (time or frequency) and Y axis (theta) values of the current Period Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

13.2.5 Info

Displays the **Info** dialog box of the current Period Window. The contents of the dialog box depend upon the selected period analysis method.

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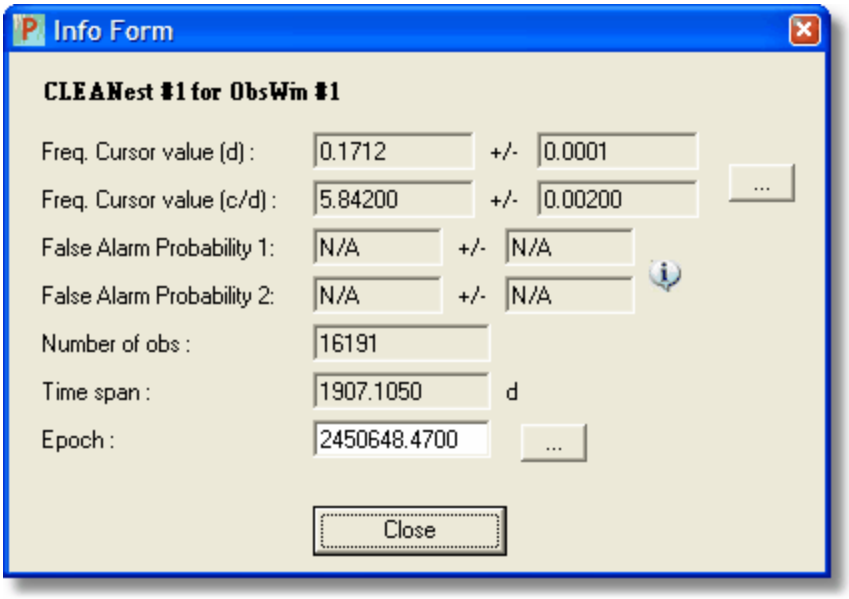

The following items are part of every Period Window **Info** dialog box :

- **Freq. Cursor value (d), Freq. Cursor value (c/d)** : displays the value of the dominant (most prominent) period in the Period Window, expressed both in cycles per day (c/d) and days (d), and calculated following the selected period analysis method. Next to the period value, also the period uncertainty or period error is given, in the field following the **+/-** symbol.

  Peranso determines the minimum period error or period uncertainty of the dominant period *P*, by calculating a 1-sigma confidence interval on *P*, using a method described by *Schwarzenberg-Czerny* (1). More information is provided in the Glossary.

- **False Alarm Probability 1, False Alarm Probability 2** : both values are used to express the significance of the dominant period P. Click the button for a brief explanation on the meaning of the False Alarm Probabilities, or consult the Glossary.

- **Number of obs** : the amount of observations used in the period analysis.

- **Time span** : the difference between the time of the last observation and the time of the first observation, used in the period analysis.

- **Epoch** : allows to set the epoch time (= starting time for calculating the phases of a Phase Window), which then is propagated to all child Phase Windows of the current Period Window. Enter the new epoch time directly in the text field, or click the button labeled "**...**" next to the Epoch field. It displays the Epoch Form.

The following items are optional and depend upon the selected period analysis method :

- **Nb, Nc** : displays the number of bins (Nb) and "covers" of Nb bins (Nc) parameters entered for a PDM or EEBLS (Nb only) period analysis.
- **Number of harmonics** : displays the number of harmonics used for an ANOVA or FALC period analysis.
- **Default MagError** : displays the default Magnitude Error value used for a FALC period

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analysis.
- **Observational mag error** : displays the observational magnitude error value used for a Renson period analysis.

The following items are only visible when doing an EEBLS period analysis :

- the EEBLS period (in days)
- the epoch of mid transit
- the transit depth
- the transit duration (in days)
- the phase of ingress (transit start)
- the phase of egress (transit end)
- the value of the Tingley Exoplanet Diagnostic
- the **Show EEBLS Fit** button to graphically display the EEBLS fit in the PhaseWin (red line). The label of the Show EEBLS Fit button changes into **Hide EEBLS Fit**, allowing to toggle the visibility of the EEBLS fit.

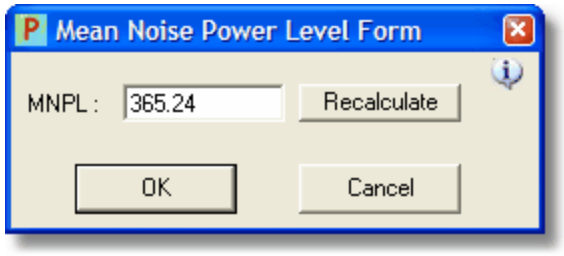
(1) Schwarzenberg-Czerny, A., 1991, Mon. Not. R. astr. Soc., 253, 198-206.

13.2.5.1 Mean Noise Power Level

To determine the minimum period error or period uncertainty of the dominant period *P*, *Peranso* calculates a 1-sigma confidence interval on *P*, using a method described by *Schwarzenberg-Czerny* (1). This method requires the so called **Mean Noise Power Level** (*MNPL*) in the vicinity of *P*.

Finding the *MNPL* may require some care in practice, as many low-power features appearing in a Period Window, are not due to noise but are window patterns of some periods, and thus should not be taken into account. *Peranso* automatically calculates an approximated *MNPL* value to determine the period uncertainty. However, you may decide to estimate the *MNPL* yourself and to enter its value in the Mean Noise Power Level form. The human eye appears to be a good *MNPL* estimator: simply look at the Period Window and estimate the mean level of the power spectrum (or equivalent) around *P*, ignoring all strong lines and their aliases.

The Mean Noise Power Level form is activated by clicking the small button labeled "**...**" in the Info dialog box.



To accept the default *MNPL* value proposed by *Peranso*, click **OK.** It closes the MNPL dialog box. Alternatively, enter your own *MNPL* value and click **OK**. The Info dialog box is updated to show the new period uncertainty, based on the newly entered *MNPL* level. The **Recalculate** button is used to let *Peranso* calculate the approximated MNPL level.

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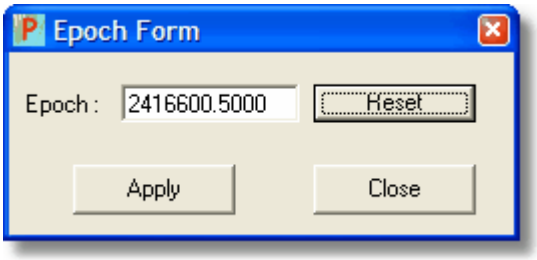
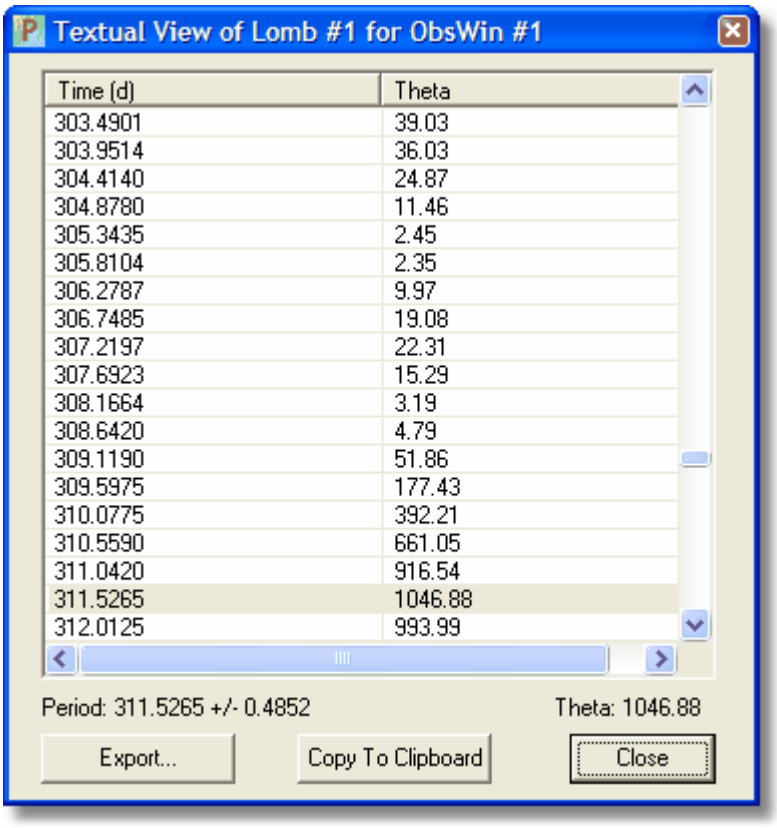
13.2.5.2 Epoch Form

The **Epoch Form** allows to set the epoch time (= starting time for calculating the phases of a Phase Window). Enter the new epoch time in the text field and click **Apply**. The Phase Window will be redrawn using the new epoch time. *Peranso* by default uses the time of the first observation in the Observations Window as the epoch time. Click **Reset** to display that default value in the Epoch text field.



13.2.6 Textual View

Displays a **Textual View** of the Period Window contents. It has two columns : the Time and Theta statistic of each period. Below is an example Textual View form.



The highlight in the two column table is placed on the line with the dominant period. Below the table is a (optional) line labeled **Period:** and **Theta:**. It displays the period value and the regular *Peranso*

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period error of the dominant period, and the corresponding theta statistic.

Remark : in case of a FALC analysis, this line displays the FALC period error, which is calculated following the algorithm provided by *Alan Harris* (JPL). It is different from the regular *Peranso* period error, which is based on a method by *Schwarzenberg-Czerny*. The latter is displayed in the Period Window Info dialog box.

- Use the **Export** button to write the contents of the Textual View form to a file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.
- Use **Copy To Clipboard** to copy the contents of the Textual View form to the Microsoft Windows clipboard.
- Use **Close** to quit the form.

13.2.7 Properties

Displays the **Properties** dialog box of the current Period Window, which is used to modify the visual appearance of most elements of the window. It contains following tabs :

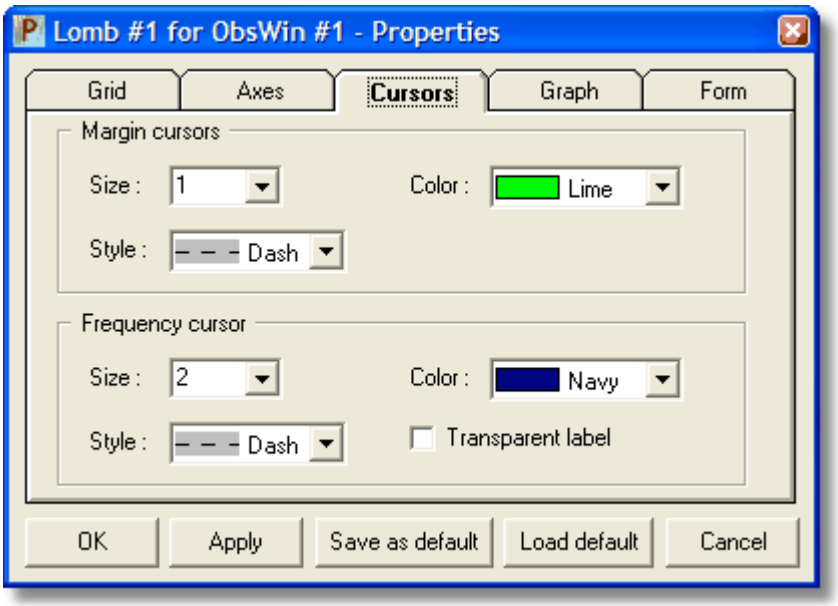
- **Grid**

  This tab is identical to the Grid tab of the Properties dialog box of an Observations Window.

- **Axes**

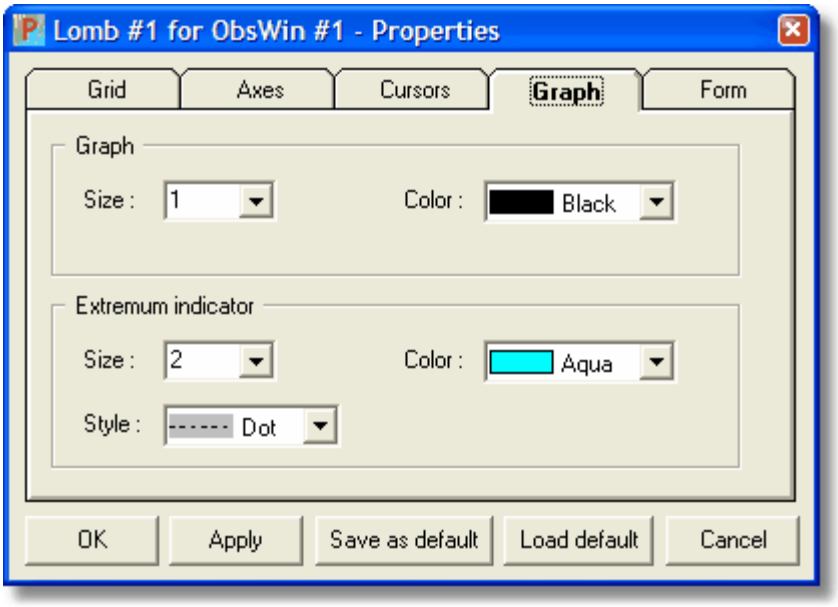
  This tab is identical to the Axes tab of the Properties dialog box of an Observations Window, except that no 'Reverse Y Axis' operation is supported.

- **Cursors**



The **Margin cursor** frame defines the line color, style and thickness of the Margin Cursors. The **Frequency cursor** frame likewise defines the line color, style and thickness of the Frequency Cursor. If the **Transparent label** option is enabled, the labels, that appear next to the Frequency Cursor, and that display its time and frequency value, will be transparent. If these values are hard to read (e.g., when drawn over a cluttered Period Window), then disable the Transparent label option. Alternatively, left click the Frequency Cursor labels directly in the Period Window. This will also toggle their transparency setting.

- **Graph**



The **Graph** frame defines the line color and thickness of the Period Window graph. The **Extremum indicator** frame defines the line color, style and thickness of the Extremum Indicator.

- **Form**

This tab is identical to the Form tab of the Properties dialog box of an Observations Window, except that (evidently) 'Hide inactive data' is not supported

The Properties dialog box contains following buttons :

- **OK** : applies the selected Property values to the current Period Window and closes the Property dialog box.
- **Apply** : applies the selected Property values to the current Period Window, without closing the Property dialog box.
- **Save as default** : saves the current Property values (of all tabs) as default values, meaning that all newly created Period Windows will employ these values.

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- **Load default** : reads the default Property values and shows them in the Property dialog box. Use **Apply** or **OK** to subsequently apply the values to the current Period Window.
- **Cancel** : closes the Property dialog box without modifying the Period Window.

13.2.8 Close

Closes the current Period Window. If unsaved data are present, the user will be asked for confirmation first.

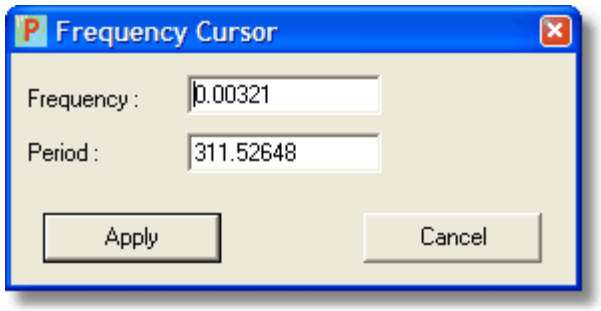
13.3 Period Analysis Menu

13.3.1 Show Frequency Cursor

Toggles the visibility of the Frequency Cursor in the current Period Window.

13.3.2 Frequency Cursor Value...

Allows to position the Frequency Cursor at a specific location in the Period Window, by entering a numerical value (instead of using the mouse) in the **Frequency Cursor** dialog box.



13.3.3 PhaseWin at Frequency Cursor Value

Displays a Phase Window corresponding with the period at the Frequency Cursor position.

13.3.4 Prominent Periods Table

Displays a table with information about the 20 most prominent periods in the current Period Window, sorted following their theta statistic (e.g., the power spectrum value in case of a Lomb-Scargle periodogram). The highest entry is called the dominant period.

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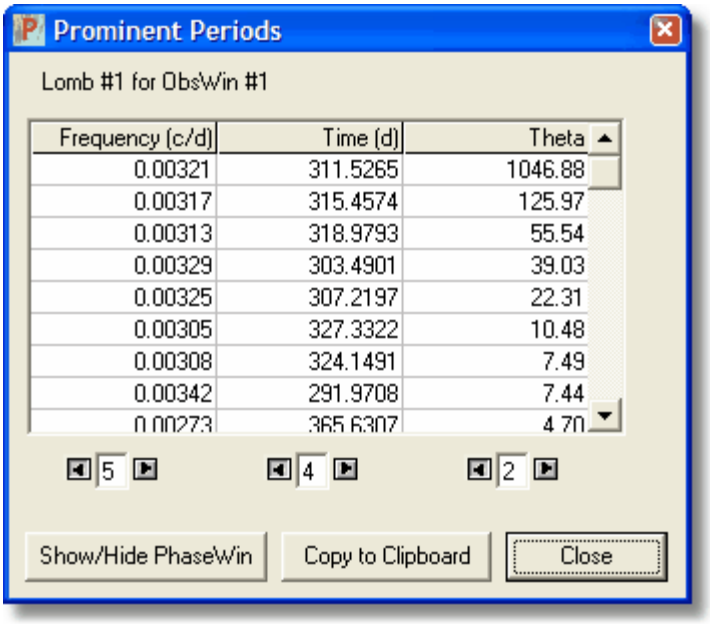

For each prominent period, the table lists the frequency, time and theta statistic. Select one or more entries in the table and click the **Show/Hide PhaseWin** button to display/hide the corresponding Phase Windows. Click the **Copy to Clipboard** button to copy the contents of the table to the Microsoft Windows clipboard. Click the **Close** button to quit the Prominent Periods Table.

Below each column are the so called Precision Indicators. They determine the number of significant digits used in displaying frequency, time and theta values. Use the left and right arrows to decrease/increase the precision, or enter the value directly in the text field. Note that the given values are used throughout *Peranso*. E.g., the Frequency Cursor value that is displayed next to the cursor, uses the precision indicated in the Prominent Periods Table.

The Precision Indicator values are persistent, i.e. *Peranso* reuses them between successive sessions.

13.3.5 Refine Period Analysis...

Displays a period analysis dialog box, in which all parameters (a/o the Start, End, Resolution values) are taken over from the current Period Window. Click the **OK** button to create a new Period Window.

A typical usage of the **Refine Period Analysis** command is to refine the accuracy and/or scan range of the period determination. Enter Start and End values that narrow the calculation interval and choose a higher Resolution value.

13.3.6 Period Significance Analysis...

Executes a significance analysis for a given period, by calculating its False Alarm Probability.

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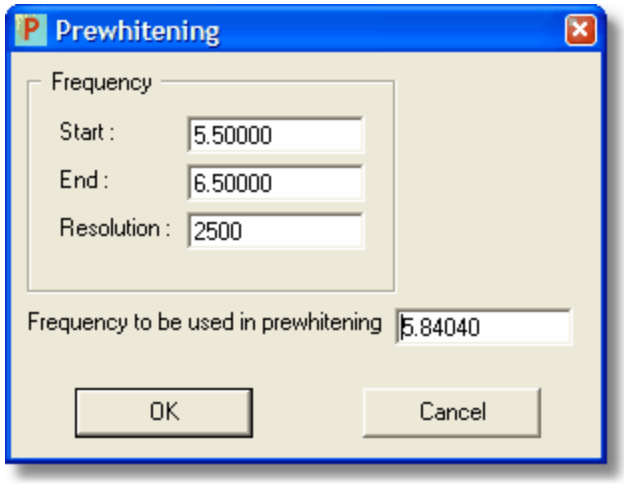
13.3.7 Prewhitening...

The technique of 'prewhitening' is used to look for multiple periods in observation data, by removing a specified period (mostly the dominant period) from the observation data (1), after which a new period analysis is started on the residual data. Doing so should make the specified period and related frequencies disappear.

The **Prewhitening** command displays a dialog box, similar to the one used for initiating the period analysis, except for one new field, labeled **Time (or frequency) to be used in prewhitening**. It allows to enter the time or frequency value of the period to be excluded (prewhitened) from the period calculations. The default value presented by *Peranso* is the one of the dominant period.



Click **OK** to start the prewhitened period analysis. It creates a new Period Window, with the prewhitening results, and with the indication "* PREWHITENED *" in its caption. Click **Cancel** to quit.

(1) This is accomplished by subtracting a sinusoid having the frequency, amplitude and phase of the specified period from the data.

13.3.8 CLEANest Workbench...

A full description of the **CLEANest Workbench** is provided in Tutorial 3.

13.4 Tools Menu

13.4.1 Julian Day Calculator

This command is identical to the Peranso Desktop Window Julian Day Calculator command.

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13.4.2 Exoplanet Diagnostic (Tingley)

This command is identical to the Peranso Desktop Window Exoplanet Diagnostic (Tingley) command.

13.5 Window Menu

This menu is identical to the Observations Window Window Menu.

13.6 Help Menu

This menu is identical to the Peranso Desktop Window Help menu.

13.7 Toolbar

The Period Window Toolbar groups following commands :

Icon	Command
	Full View
	Set/unset Left Margin Cursor
	Set/unset Right Margin Cursor
	Find Extremum
	Refine Period
	Set/unset Frequency Cursor
	PhaseWin at Frequency Cursor value
	Prominent Periods Table

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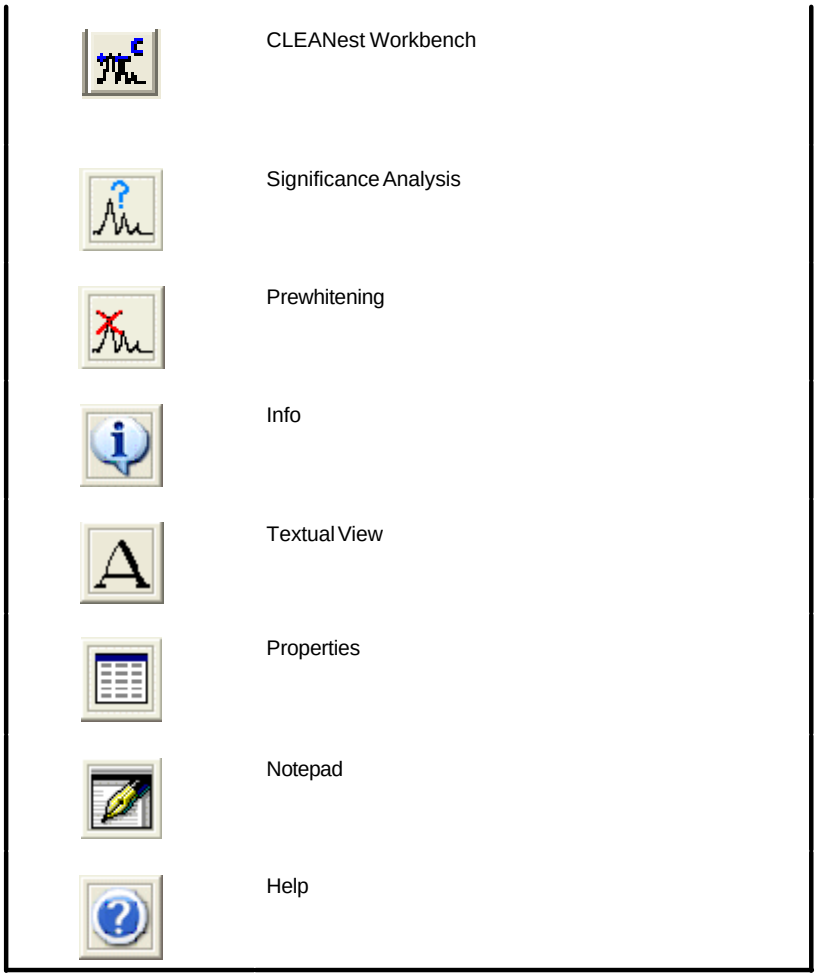
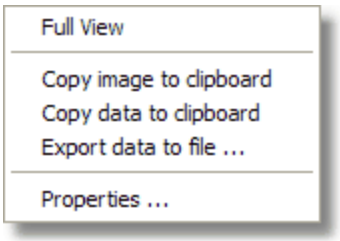


13.8 Period Window Context Menu

Click the right mouse button to pop up the Period Window Context Menu, while the mouse cursor is anywhere inside the PerWin.



- **Full View**

  Changes the X- and Y-axis limits (axes minimum and maximum values) such that all data are displayed in the current Period Window. Grid lines and axes annotation are drawn at 'easy-to-read' values

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- **Copy Image to Clipboard**

  Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

- **Copy Data to Clipboard**

  Copies the X axis (time or frequency) and Y axis (theta) values of the current Period Window to the Microsoft Windows Clipboard.

- **Export Data to File**

  Saves the X axis (time or frequency) and Y axis (theta) values of the current Period Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

- **Properties**

  Displays the Properties dialog box of the current Period Window.

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Part XIV

14 The Phase Window

14.1 File Menu

This menu is identical to the Observations Window File Menu.

14.2 Phase Window Menu

14.2.1 Full View

Changes the X- and Y-axis limits (axes minimum and maximum values) such that all data are displayed in the current Phase Window. Grid lines and axes annotation are drawn at ‘easy-to-read’ values.

14.2.2 Single Phase View

Changes the view of the current Phase Window, folding all data over a phase range from 0.0 to 1.0.

14.2.3 Double Phase View

Changes the view of the current Phase Window, folding all data over a phase range from 0.0 to 2.0.

14.2.4 Fit Curve

Calculates the mean curve of all phase data in the Phase Window, using a spline interpolation method. A user can modify the visual appearance of the mean curve using the Properties dialog box.

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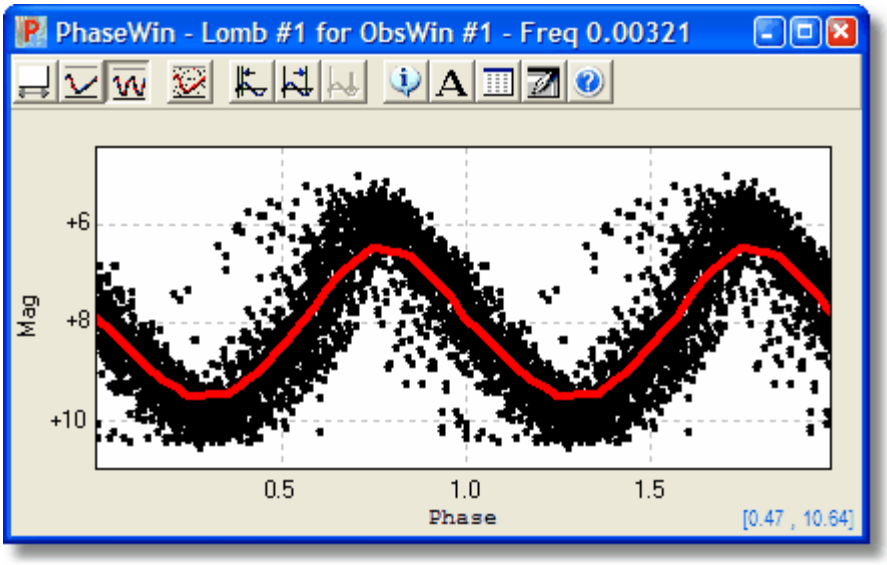

14.2.5 Copy Image to Clipboard

Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

14.2.6 Copy Data to Clipboard

Copies the X axis (phase) and Y axis (mostly magnitude) values of the current Phase Window to the Microsoft Windows Clipboard.

14.2.7 Export Data to File...

Saves the X axis (phase) and Y axis (mostly magnitude) values of the current Phase Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

14.2.8 Info...

Displays the **Info** dialog box of the current Phase Window. It is identical to the Period Window Info dialog box. If a Fit Curve operation has been executed on the current Phase Window, then the mean amplitude value of the fitted curve is displayed in the **Info** dialog box as well.

Remark : similar to the Period Window Info dialog box, one can set the epoch time (= starting time for calculating phases), but in this case the setting is limited to the current Phase Window and not propagated to other Phase Windows.

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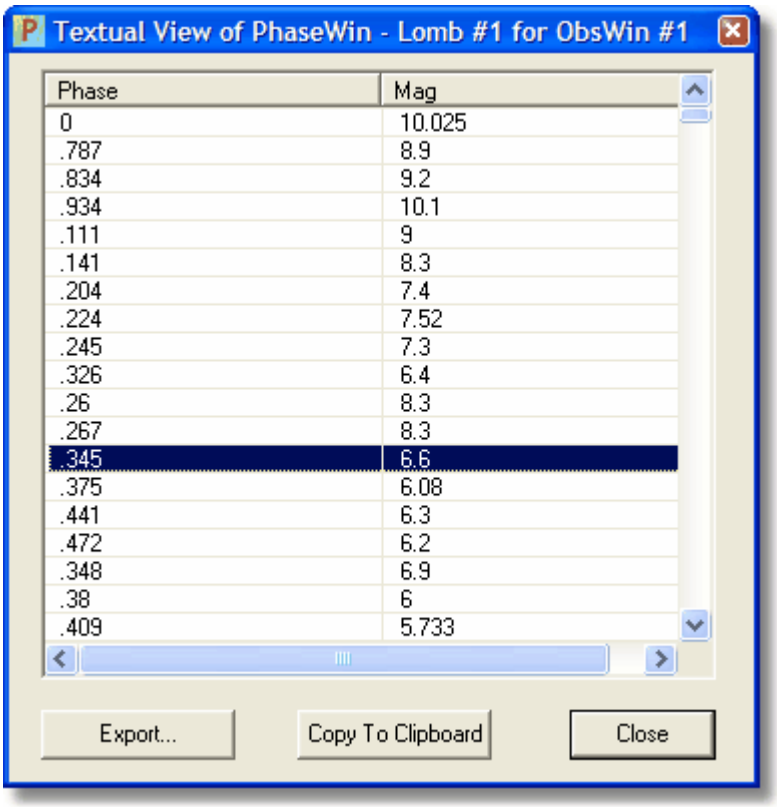
14.2.9 Textual View...

Displays a **Textual View** of the Phase Window contents. It has two columns : the Phase and Mag values of each phase element. Below is an example Textual View form.



- Use the **Export** button to write the contents of the Textual View form to a file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.
- Use **Copy To Clipboard** to copy the contents of the Textual View form to the Microsoft Windows clipboard.
- Use **Close** to quit the form.

14.2.10 Properties...

Displays the **Properties** dialog box of the current Phase Window, which is used to modify the visual appearance of most elements of the window. It contains following tabs :

- **Grid**

  This tab is identical to the Grid tab of the Properties dialog box of an Observations Window.

- **Axes**

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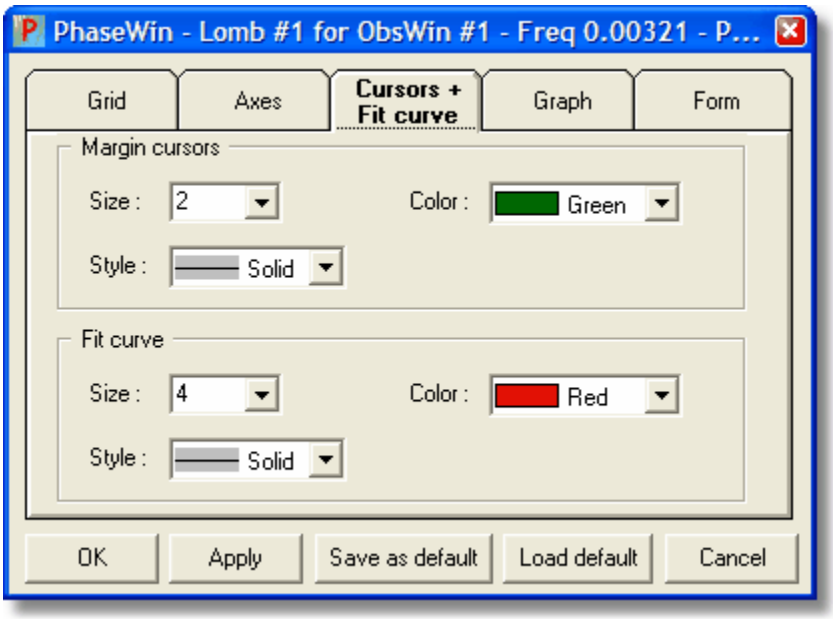
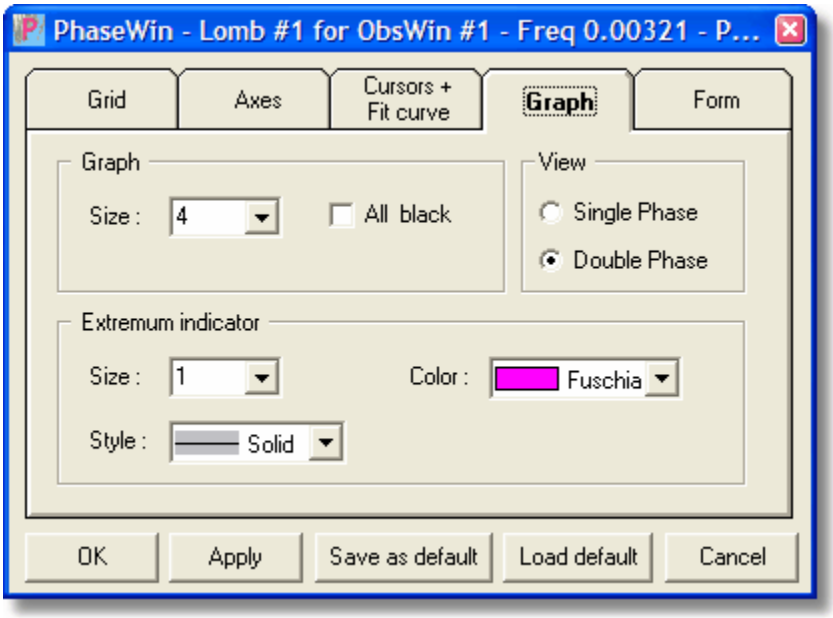
This tab is identical to the Axes tab of the Properties dialog box of an Observations Window, except that no 'Reverse Y Axis' operation is supported.

- **Cursors + Fit Curve**



The **Margin cursors** frame defines the line color, style and thickness of the Margin Cursors. The **Fit curve** frame likewise defines the line color, style and thickness of the Fit Curve.

- **Graph**



The **Graph** frame defines the size of the dots used for drawing the phases of the observations.

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Each dot represents one observation, and is drawn in the same color as the corresponding observation in the Observations Window. Click the **All black** check box to draw all dots in black color. The **View** frame allows to switch between Single Phase View and Double Phase View. The **Extremum indicator** frame defines the line color, style and thickness of the Extremum Indicator.

- **Form**

  This tab is identical to the Form tab of the Properties dialog box of an Observations Window, except that (evidently) 'Hide inactive data' is not supported

The Properties dialog box contains following buttons :

- **OK** : applies the selected Property values to the current Period Window and closes the Property dialog box.
- **Apply** : applies the selected Property values to the current Period Window, without closing the Property dialog box.
- **Save as default** : saves the current Property values (of all tabs) as default values, meaning that all newly created Period Windows will employ these values.
- **Load default** : reads the default Property values and shows them in the Property dialog box. Use **Apply** or **OK** to subsequently apply the values to the current Period Window.
- **Cancel** : closes the Property dialog box without modifying the Period Window.

14.2.11 Close

Closes the current Phase Window. If unsaved data are present, the user will be asked for confirmation first.

14.3 Tools Menu

This menu is identical to the Period Window Tools menu.

14.4 Window Menu

This menu is identical to the Observations Window Window Menu.

14.5 Help Menu

This menu is identical to the Peranso Desktop Window Help menu.

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14.6 Toolbar

The Phase Window Toolbar groups following commands :

Icon	Command
	Full View
	Single Phase View
	Double Phase View
	Fit Curve
	Set/unset Left Margin Cursor
	Set/unset Right Margin Cursor
	Find Extremum
	Info
	Textual View
	Properties
	Notepad
	Help

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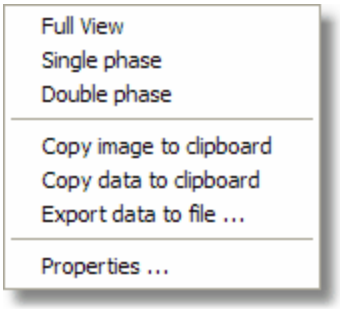
14.7 Phase Window Context Menu

Click the right mouse button to pop up the Phase Window Context Menu, while the mouse cursor is anywhere inside the PhaseWin.



- **Full View**

  Changes the X- and Y-axis limits (axes minimum and maximum values) such that all data are displayed in the current Phase Window. Grid lines and axes annotation are drawn at 'easy-to-read' values.

- **Single Phase**

  Changes the view of the current Phase Window, folding all data over a phase range from 0.0 to 1.0.

- **Double Phase**

  Changes the view of the current Phase Window, folding all data over a phase range from 0.0 to 2.0.

- **Copy Image to Clipboard**

  Creates a bitmap copy of the current *Peranso* window and places it on the Microsoft Windows clipboard. The toolbar of the active window is never copied.

- **Copy Data to Clipboard**

  Copies the X axis (phase) and Y axis (mostly magnitude) values of the current Phase Window to the Microsoft Windows Clipboard.

- **Export Data to File**

  Saves the X axis (phase) and Y axis (mostly magnitude) values of the current Phase Window to a text file. The user will be prompted to enter the location and name of the file, using a standard Microsoft Windows File Save dialog box.

- **Properties**

  Displays the Properties dialog box of the current Phase Window.

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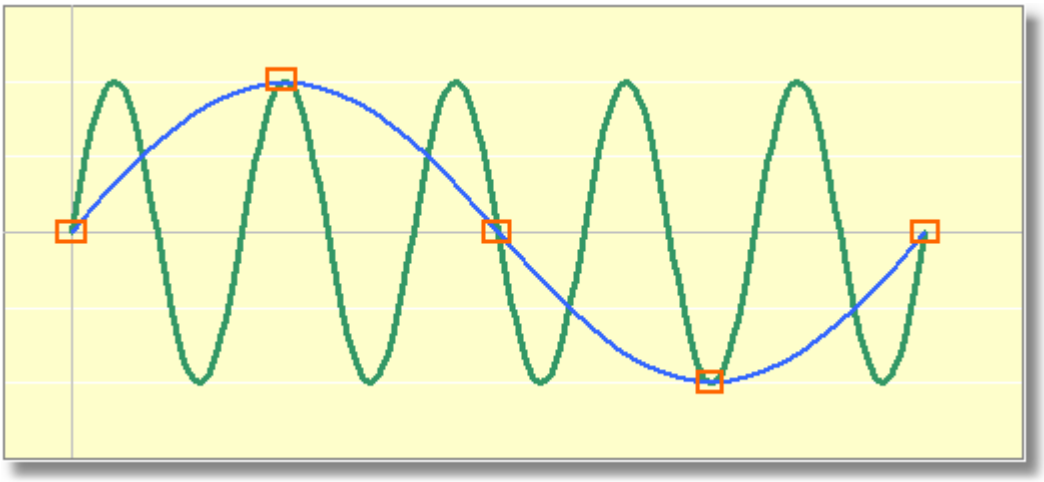
Part

15 Glossary

15.1 Aliasing

An alias for a period causes false peaks in the Period Window, which are artifacts of the interval between observations (the 'sampling rate'). An alias masquerades as another period, where the data seemingly fits as well as the correct period. It differs from the true period by an integral fraction, e.g., 5/2, 1/6, etc. This often happens if a single observation session does not cover a complete cycle of the variable or asteroid, and if the next run, also incomplete, is many cycles removed.

Aliases are quite common in astronomical time-series. E.g., assume a variable star with a period of 0.8 days (green curve below). You make observations each consecutive night at almost exactly the same time (orange boxes). If you do a period analysis on your observations, you will find a peak (a/o) at 4 days, but this is not the result of the star varying on a 4 day period. It is the result of a sine wave (blue curve) that fits your observations.



The *Peranso* Spectral Window command calculates the pattern caused by aliasing. It displays not a true Fourier spectrum for a star, but indicates what peaks are artifacts of your sampling. It is typically used in combination with any of the regular period analysis methods, and is used to demonstrate that the period found can not be the result of the data sampling.

One way to avoid aliasing is to ensure that your observation rate ('sampling rate') is "sufficiently" high. Always estimate the time between observations in your light curve. The smallest period that you can successfully measure in your data will have a value twice your sampling timescale. E.g., if you obtained observations every 2 minutes, the shortest period that you can accurately determine is 4 minutes. Shorter periods will not be well determined. This is the so called Nyquist criterion. Expressed in the frequency domain : if the time between observations is t, then the frequency at which to cut off your analysis is 1/2t, the Nyquist frequency.

In mathematical jargon :

If a sinusoid of frequency f (in cycles per day) is sampled s times per day, with $s = f/2$, the resulting samples will also be compatible with a sinusoid of frequency $f - 2s$. Each sinusoid becomes an alias for the other. To avoid aliasing, you must make sure that the signal does not contain any sinusoidal component with a frequency greater than $s/2$. This is equivalent to saying that the sampling frequency s must be strictly greater than twice the signal's bandwidth (i.e., the difference between the maximum and minimum frequencies of its sinusoidal components).

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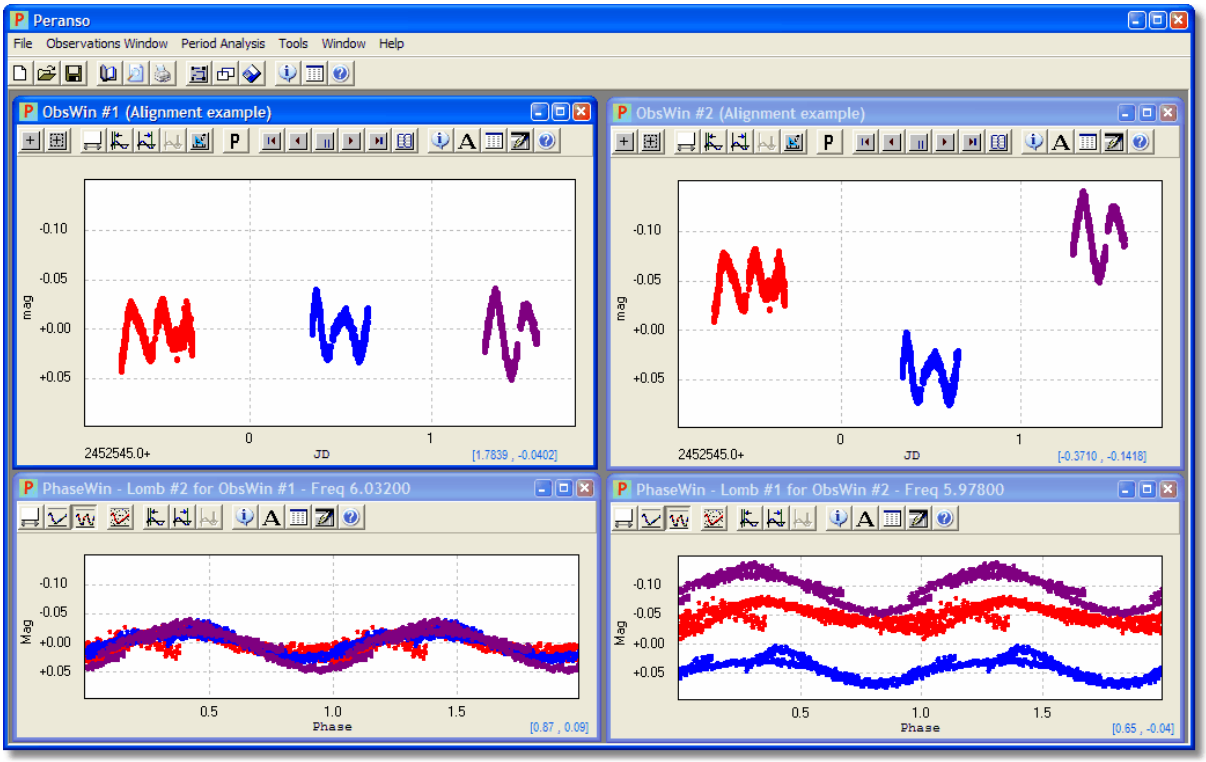
15.2 Alignment of Observation Sets

The alignment of Observation Sets often is critical to finding the right period, since a period determination method can find a different dominant period for different ObsSet alignments. In many cases, you will have to adjust ObsSets so that they mesh well together, before you start the period analysis. This process is sometimes called zero-point adjustment. The alignment is not always mandatory, and very much depends on the particular characteristics of the observations (e.g., usage of filters, similarities between observing instruments, evolution of light curve over time, etc.).

By adjusting an ObsSet, you move it up or down in relation to the other ObsSets in the ObsWin. By doing this, you can get the data for a given ObsSet to line up with the data from other ObsSets. In some cases (for instance, when working with unfiltered differential variable star magnitudes obtained by different observers) this is not very easy.

In the example below, we see how alignment of observation sets affects the Phase Windows. Top row left : Observation Window with correctly aligned observation sets. Top row right : the same observation sets before alignment. Bottom row left : Phase Window resulting from correctly aligned observation sets. Bottom row right : Phase Window resulting from misaligned observation sets.



15.3 Dominant Period

The Dominant Period is the most prominent period of a Period Window. It corresponds with the highest peak or deepest valley in the Period Window, depending on the selected period analysis method.

The Prominent Periods Table displays an overview of the 20 most prominent periods in a Period Window. The top entry of this table is the Dominant Period.

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Please note that the Dominant Period is not necessarily the true period (or exact period) of the object under analysis. Some peaks or valleys arise from aliasing, others may be harmonics of the main (fundamental) frequency, etc. Even if a period is a true period, it may not be significant. Evidently, *Peranso* offers a series of tools to try to distinguish true periods from artifacts and to determine the significance level of a period.

15.4 False Alarm Probability

The False Alarm Probability (FAP) is a metric to express the significance of a period. A False Alarm arises in period analysis techniques when incorrectly a period is found where none exists in reality. The lower the FAP for a given period *P*, the more likely *P* is a significant period. FAP values are expressed as a number between 0 and 1.

As a rule of thumb : FAPs below 0.01 (1%) mostly indicate very secure periods, and those between 0.01 and 0.20 are far less certain. Anything above 0.20 (20%) mostly relates to an artifact in your data, instead of a true period.

Peranso calculates two FAPs as part of a period significance analysis for a given period *P*. The first FAP is the probability that there is no period in the Period Window with value *P*. The second FAP is the probability that the observations contain a period that is different from *P*.

15.5 Harmonics

An harmonic is a signal whose frequency is an integral multiple of the frequency of some reference signal. For a signal whose main frequency is *f*, the second harmonic has a frequency *2f*, the third harmonic has a frequency of *3f*, and so on. Signals occurring at frequencies of 2f, 4f, 6f, etc. are called even harmonics; the signals at frequencies of 3f, 5f, 7f, etc. are called odd harmonics.

15.6 Magnitude Error

The Magnitude Error (MagError) of an observation represents the error in the magnitude estimate. A MagError value is visually represented as a 'vertical bar' centered around the corresponding magnitude dot in the Observations Window. The bar extends above and below the observation by the amount of the error. For example, if the magnitude error is 0.1 mag, the total bar height is 0.2 mag, indicating the value is meant to be taken as +/- the amount.

Magnitude error values are taken into account when performing a period analysis calculation using the FALC method.

15.7 Observation Attributes

Each observation in *Peranso* is defined by following attributes :

- Time (mostly Julian Date, JD)
- Magnitude (or intensity)

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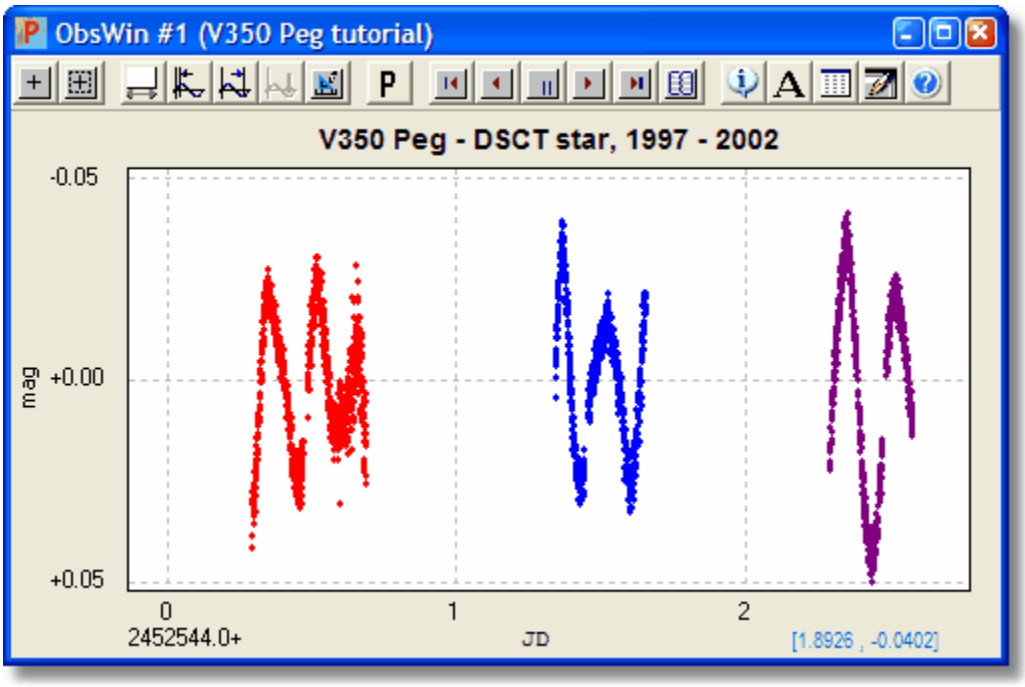
- Magnitude Error (MagError) [optional]: the error in the magnitude estimate. The concept is explained elsewhere in this Glossary.

- Use status [optional]. Has a value of 0 or 1 and determines if an observation is considered to be active (1) or inactive (0). The concept is explained elsewhere in this Glossary.

15.8 Observation Set

Observations in *Peranso* are grouped in observation sets. Observation sets are typically used to make logical partitions in large volumes of observations, e.g., to partition per night or per observer. *Peranso* offers an extensive set of commands that operate on all observations of an observation set at once (e.g., to average an observation set).

The example below shows three observation sets with observations of V350 Peg, obtained during 3 successive nights.



Observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

15.9 Period Error

Peranso determines the minimum period error or period uncertainty of the dominant period *P*, by calculating a 1-sigma confidence interval on *P*, using a method described by *Schwarzenberg-Czerny* (1). This method is a so-called 'post-mortem analysis' and measures the width and heights of peaks/valleys in a Period Window.

In his paper, Schwarzenberg-Czerny points out that most of the classical error estimation methods (some of which are present in other period analysis software) are unreliable. That's the main reason why these methods are not supported in *Peranso*, despite their simplicity and speed of calculation.

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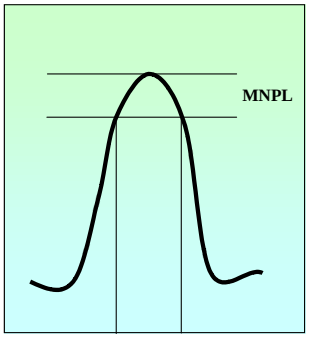
The period uncertainty method of Schwarzenberg-Czerny requires the so called **Mean Noise Power Level** (*MNPL*) in the vicinity of *P*. The 1-sigma confidence interval on P then is equal to the width of the line at the *P – MNPL* level.



The 1-sigma interval corresponds to the width of the line at level MNPL down from the peak

Finding the *MNPL* may require some care in practice, as many low-power features appearing in a Period Window, are not due to noise but are window patterns of some periods, and thus should not be taken into account. *Peranso* automatically calculates an approximated *MNPL* value to determine the period uncertainty. However, you may decide to estimate the *MNPL* yourself and to enter its value in the Mean Noise Power Level form. The human eye appears to be a good *MNPL* estimator: simply look at the Period Window and estimate the mean level of the power spectrum (or equivalent) around *P*, ignoring all strong lines and their aliases.

(1) Schwarzenberg-Czerny, A., 1991, Mon. Not. R. astr. Soc., 253, 198-206.

15.10 Period Significance

Peranso determines the significance of a period by calculating the False Alarm Probability (FAP) for that period, using a *Fisher Randomization Test* (1). This test executes the selected period analysis calculation repeatedly (at least 100 times), each time shuffling the magnitude values of the observations to form a new, randomized observation set, but keeping the observation times fixed (2). This randomization and period calculation loop is performed for the number of permutations specified by the user. Evidently, a Fisher Randomization Test takes a considerable amount of time to execute.

Using a Fisher Randomization Test, *Peranso* calculates 2 complimentary False Alarm Probabilities, used for determining the significance of a period *P :*

- **FAP 1** represents the proportion of permutations that contain a period with a peak/valley higher resp. lower than the peak/valley of *P* at ANY frequency. It is the probability that there is no period in the Period Window with value *P*.

- **FAP 2** represents the proportion of permutations that contain a period with a peak/valley higher resp. lower than the peak/valley of *P* at EXACTLY the frequency of *P*. It is the probability that the observation data contain a period that is different from *P*.

1-sigma errors are given on both FAP values. The lower the FAP for a given period *P*, the more likely *P* is a significant period. FAP values are expressed as a number between 0 and 1.

As a rule of thumb : FAPs below 0.01 (1%) mostly indicate very secure periods, and those between

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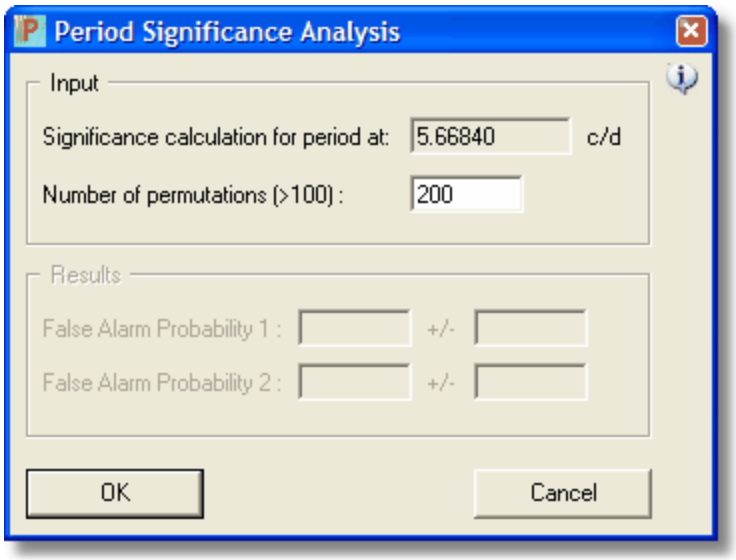
0.01 and 0.20 are far less certain. Anything above 0.20 (20%) mostly relates to an artifact in your data, instead of a true period.

Peranso displays the **Period Significance Analysis** dialog box to determine the significance of a period *P*. A full description of the dialog box is provided in Tutorial 2.



Remark

Many of the false alarm probability formulae presented in literature (and implemented in other period analysis software) are unreliable. A few examples : the *F-test* of the PDM method is incorrect, as demonstrated by Heck et al. (3). The well-known *Lomb-Scargle false alarm probabilities* are also incorrect, because they use the Horne and Baliunas equation for the number of independent frequencies, which has been shown to be incorrect (4).

Although much simpler and faster to calculate, these traditional FAP formulae therefore have not been implemented in *Peranso*.

(1) More precisely, *Peranso* executes a *permutation test* or *Monte Carlo Permutation Procedure* (MCPP). Permutation tests are special cases of *randomization tests*, i.e., tests that use randomly generated numbers for statistical inference.
(2) This is the so called *Bootstrap method*. See Press, W.H. et al., 1992, Numerical Recipes : The Art of Scientific Computing, 2 nd ed, New York, Cambridge Univ. Press.
(3) Heck, J., Manfroid, A., Mersch, G., 1985, Astron. Astrophys. Suppl. Ser., 59:63-72.
(4) Cumming, A., Marcy, G.W., Butler, R.P., 1999, The Astrophysical Journal, 526:890-915.

15.11 Use Status

The Use status of an observation has a value of 0 or 1 and determines if an observation is considered to be active (1) or inactive (0). Inactive observations are not taken into account when performing a period analysis calculation. Observations can be made active and inactive at every moment, using the mouse and keyboard. An active observation is plotted as a filled circle in an Observation Window. Inactive observations appear as open circles.

The example below shows an observation set of V350 Peg, in which 3 observations have been made inactive.

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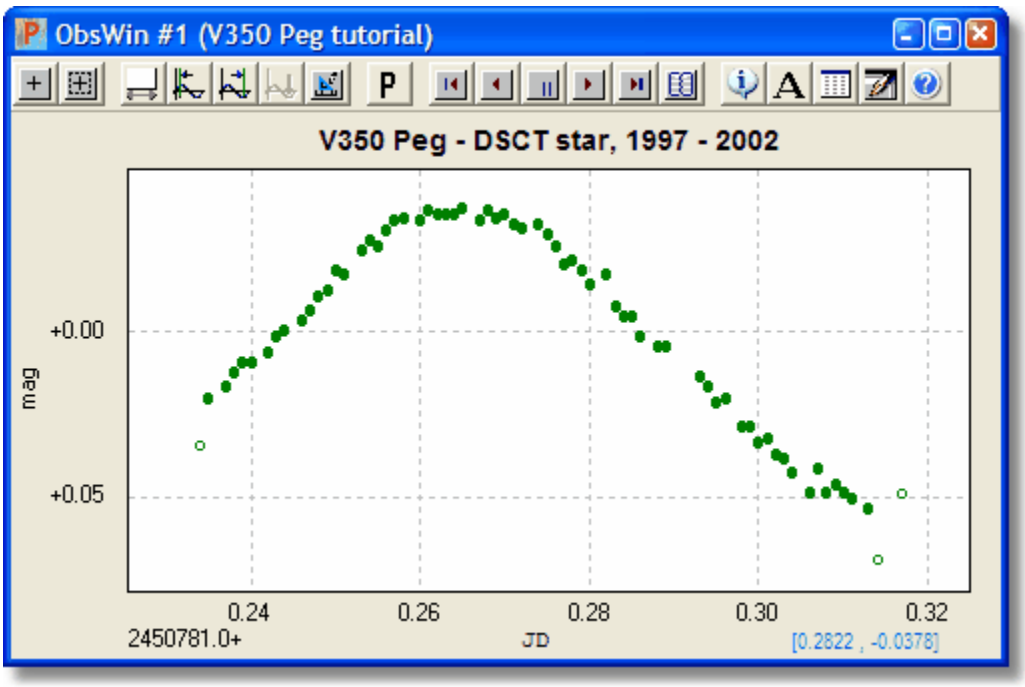

Observations kindly provided by Paul Van Cauteren, Belgium. Published in *Follow-up observations of the DSCT star V350 Peg*, J. Vidal-Sainz, E. García-Melendo, P. Lampens, P. Van Cauteren, P. Wils, **Communications in Asteroseismology**, 143, (2003).

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Part

16 Appendices

16.1 Appendix 1 : example AIP4WIN v1.4 file

The *Peranso* Add Observation Set command allows to import observations from various predefined file formats. One of them is the AIP4WIN **(*AIP for Windows)* v 1.4 format**, produced by the photometry tool of AIP4WIN.

Below is an example AIP4WIN v1.4 file to illustrate the file format. *Peranso* automatically extracts the observations from the file, retrieving their time (JD) and V-C magnitude. All observations are bundled in one observation set.

AIP4Win Multi-Image Photometry Tool
Analysis of 118 images from directory: F:\TVM\CCDOPS\Jan02\uzboo_moonlight\raw
Radius of star diaphragm: 3
Sky annulus inner radius: 7
Sky annulus outer Radius: 10
Search Radius: 10
Initial Comparison Star coords: X=94.07, Y=241.74
Initial Variable Star coords: X=108.00, Y=131.00
Initial Check Star coords: X=75.53, Y=125.12
Image time = time in FITS file header or log file.

Image	Date	Time	Exp	ADU Com	ADU Sky	ADU Var	V-C mag	ADU Chk	K-C mag
u-002.fit	2004-01-03	02:44:28	90	133524.0	6319.8	1141.5	5.170	57811.6	0.909
u-004.fit	2004-01-03	02:46:48	120	181083.8	8295.9	1154.8	5.488	77029.2	0.928
u-005.fit	2004-01-03	02:48:56	120	177025.5	8248.1	1834.2	4.961	77226.0	0.901
u-006.fit	2004-01-03	02:51:04	120	174409.6	8185.5	1959.1	4.874	75722.6	0.906
u-007.fit	2004-01-03	02:53:12	120	170340.0	8039.7	1154.7	5.422	73977.9	0.906
u-008.fit	2004-01-03	02:55:20	120	174247.1	7929.1	1143.7	5.457	75828.1	0.903
u-009.fit	2004-01-03	02:57:28	120	173979.8	7881.6	962.5	5.643	75571.8	0.905
u-010.fit	2004-01-03	02:59:35	120	174026.2	7671.5	938.3	5.671	75602.3	0.905
u-011.fit	2004-01-03	03:01:43	120	166607.5	7490.6	1423.2	5.171	71597.7	0.917
u-012.fit	2004-01-03	03:03:50	120	163530.8	7335.1	1966.9	4.800	70230.0	0.918
u-013.fit	2004-01-03	03:05:58	120	162075.4	7344.4	971.8	5.555	69714.4	0.916
u-014.fit	2004-01-03	03:08:04	120	157303.0	7425.7	741.4	5.817	68357.4	0.905
u-015.fit	2004-01-03	03:10:12	120	155134.5	7394.6	1874.0	4.795	66791.1	0.915
u-016.fit	2004-01-03	03:12:19	120	151670.6	7290.1	900.9	5.566	65110.2	0.918
u-017.fit	2004-01-03	03:14:27	120	147823.1	7280.6	1552.9	4.947	63819.1	0.912
u-018.fit	2004-01-03	03:16:34	120	143120.9	7397.2	227.6	6.996	61113.2	0.924
u-019.fit	2004-01-03	03:18:43	120	136655.2	7458.4	944.1	5.402	59506.4	0.903
u-020.fit	2004-01-03	03:20:50	120	132894.3	7505.6	1415.5	4.931	56050.6	0.937
u-021.fit	2004-01-03	03:22:57	120	124102.0	7498.9	320.6	6.470	53955.6	0.904
u-022.fit	2004-01-03	03:25:05	120	131933.2	7503.5	1107.4	5.190	56660.9	0.918
u-023.fit	2004-01-03	03:27:13	120	130643.8	7502.9	1423.0	4.907	55531.9	0.929
u-024.fit	2004-01-03	03:29:20	120	129721.6	7562.0	852.8	5.455	55608.5	0.920
u-025.fit	2004-01-03	03:31:28	120	120729.7	7822.4	1273.1	4.942	51864.9	0.917
u-026.fit	2004-01-03	03:33:34	120	108234.0	7797.5	983.9	5.104	46269.1	0.923
u-027.fit	2004-01-03	03:35:41	120	120287.5	7670.1	839.7	5.390	50747.7	0.937
u-028.fit	2004-01-03	03:37:47	120	109990.5	7618.3	257.0	6.579	46534.1	0.934
u-029.fit	2004-01-03	03:39:55	120	115143.4	7562.9	964.6	5.192	48935.0	0.929

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16.2 Appendix 2 : example AAVSO file

The *Peranso* Add Observation Set command allows to import observations from various predefined file formats. One of them is the **AAVSO format** (*American Association of Variable Star Observers*)**.** This is the file format you get when downloading observations from the AAVSO web site, using their *Download data* option in the section *Access Data*.

Below is an example AAVSO file to illustrate the file format. *Peranso* automatically extracts the observations from the file, retrieving their time (JD) and magnitude. Fainter-than observations are skipped, but 'uncertain' observations are kept. All observations are bundled in one observation set.

```
AAVSO VALIDATED RAW DATA
******************************************************************************
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efforts and expertise of the volunteer observers who contribute the data
and the AAVSO Headquarters technical staff who prepare and maintain the
database with high quality-control standards.

If you use AAVSO observations in your research, we request acknowledgement
on behalf of the observers and the AAVSO. Our policy on this acknowledgement
is as follows:

(1) ACKNOWLEDGEMENT FOR DATA CORRELATION/REFERENCE:  If AAVSO data
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     analyzed, and play a substantive role in the interpretation of
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     a co-author of the publication.  As a co-author the AAVSO
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        - Waagen, E. O. 2004, Observations from the AAVSO International
          Database, private communication.

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**==========================================**
******************************************************************************

  col 1 - 8: Designation    col 5 is always + or - only
                            cols 1-4 and 6-7 always digit
                            col 8 alpha or blank (never digit)

      col 9: Blank

  col 10-19: Name           variable name, alphanumeric, must start in col 14

  col 20-26: Blank

  col 27-39  JD             JD and GMAT of observation (nnnnnnn.nnnn)
                            NOTE! that if GMAT goes to 5 places, the fifth
                            place is in column 43 (overlapping next field).

  col 30     Fainter-than   blank, or symbol '&lt;' (fainter-than) or '&gt;'
                            (brighter-than) or '-' (minus sign for magnitude
                            brighter than zero)

  col 40-46  Magnitude      decimal point always in col 43
                            NOTE! that if mag goes to 2 or 3 decimal places,
                            the second decimal place overlaps the : column and
                            the third decimal place overlaps the first column
                            of the Comments field.
                            If magnitude is 0.0, observation is a letter/step
                            estimate or flare star observation. See explanation
                            below under Codes/Flags Columns, sections 3)
                            and 4). Column 36 may have a colon (:) meaning
                                  estimate was uncertain.
```

```
  col 38-44  Comments       blank or non-visual band codes (such as PEP, CCD,
                            CCDV, PTG, PV, etc.)

  col 45-49  Observer       AAVSO Observer Initials, must begin in col 61,
                            1 to 5 letters (may also have digits but not in
                            first character)
                            NOTE! that some observer initials consist of
                            a 3-letter code for an institution and a 2-digit
                            number identifying the individual; these are for
                            observers using a group resource or an automated
                            telescope. Example: UMB01

  col 50-    Text           Blank, or text associated with the record.
                            NOTE! that in the very near future, the columns
                            after 67 will contain information on compstars
                            and chart used to make the observation.

CODES/FLAGS APPEARING IN THE DATABASE


Notes

1) (54-60) Non-visual observation tag or special type of observation
CCD      CHARGE-COUPLED DEVICE (Unfiltered)
CCDB     CHARGE-COUPLED DEVICE (Johnson Blue filter)
CCDI     CHARGE-COUPLED DEVICE (Johnson or Cousins Infrared filter)
CCDO     CHARGE-COUPLED DEVICE (Orange filter)
CCDR     CHARGE-COUPLED DEVICE (Johnson or Cousins Red filter)
CCDU     CHARGE-COUPLED DEVICE (Johnson Ultraviolet filter)
CCDV     CHARGE-COUPLED DEVICE (Johnson Visual filter)
CCD-IR   CHARGE-COUPLED DEVICE (Unfiltered but with IR-blocker)
CCD-RIR  CHARGE-COUPLED DEVICE (Unfiltered but with R- and IR-blockers)
CR       CHARGE-COUPLED DEVICE (Unfiltered but reduced using R magnitudes)
CV       CHARGE-COUPLED DEVICE (Unfiltered but reduced using V magnitudes)
PEPB     PHOTOELECTRIC PHOTOMETER (B BAND)
PEPH     PHOTOELECTRIC PHOTOMETER (H BAND)
PEPJ     PHOTOELECTRIC PHOTOMETER (J BAND)
PEPV     PHOTOELECTRIC PHOTOMETER (V BAND)
PTG      PHOTOGRAPHIC (BLUE)
PV       PHOTOVISUAL
WP       WEDGE PHOTOMETER
BLUE     BLUE FILTER (visual observation)
GREEN    GREEN FILTER (visual observation)
RED      RED FILTER (visual observation)
YELLOW   YELLOW FILTER (visual observation)
COMB     COMBINED NUCLEAR AND NEBULAR REGIONS
NUC      NUCLEAR REGION ONLY

2)  Step or letter magnitude
Magnitude is 0.0 and unreduced step or letter magnitude begins in col. 54.
Examples:  &lt;A ; )T; =F ; ~.3&lt;L ; C3V7D ; G1V2H' ; STEP 37 ; NOSEE
Occasionally a step/letter magnitude that has been reduced will still carry
the step/letter string in the comment field.

3) Other
a)Flare-star: i) magnitude usually 0.0 and comment field has "NOFLARE" or "NF"
              ii) time range and magnitude may be given (i.e., the observer
                  watched the star continuously from time A to time B and no
                  flare was seen); 4 digits of starting time given after JD,
                  decimal point and 4 digits of stopping time given starting
                  in col 54. Example:
Example: 1014+20      AD LEO           2451234.5678     9.5   .6012  WEO

b) Archival interval comments
In this earliest interval of data, there may be assorted additional comments
or notes relating to sequence, identification of variable, identification of
observer, or other items related to interpreting the non-standardized
observations and reports of the era. Eventually these comments will be moved
beyond column 67.

**BEGIN**
0942+11  R LEO            2416160.6      9.0:         YAS
0942+11  R LEO            2416188.5      9.3:         YAS
0942+11  R LEO            2416194.6      9.3:         YAS
0942+11  R LEO            2416222.6      9.6:         YAS
0942+11  R LEO            2416225.6     10.0   V1Z    EA

<...>

0942+11  R LEO            2453666.6042   8.9          SSW
0942+11  R LEO            2453667.7743   9.0          BXE
0942+11  R LEO            2453672.5924   9.0          SSW
0942+11  R LEO            2453672.651    8.7          LTO
0942+11  R LEO            2453674.6194   9.4          OCR
**END**
*******************************************************************************
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```
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*******************************************************************************

CODES/FLAGS
```

16.3 Appendix 3 : example ASAS format

The *Peranso* Add Observation Set command allows to import observations from various predefined file formats. One of them is the **ASAS** (All Sky Automated Survey) **format.** This is the file format you get when copying observations from the ASAS website (select **Photometric Catalog** -> **Search** -> **Get Data**) to your Microsoft Windows clipboard

Below is an example ASAS file to illustrate the file format. *Peranso* automatically extracts the observations from the file, retrieving their time (HJD) and magnitude. The latter is retrieved from the first column containing magnitude values. Fainter-than observations are skipped. All observations are bundled in one observation set.

```
# The All Sky Automated Survey Data
# gp@sirius.astrouw.edu.pl
#
# The ASAS Photometric Catalog is maintained separately for each
# observed field, so for some stars independent datasets of
# measurements are available. Their mean magnitudes may slightly differ.
#
# In each dataset (starting with #dataset=0,1,2,...):
# desig is ASAS designation (they may differ (by 1) at the last
# digit of the RA & DEC fields
# cra, cdec are initial Catalog coordinates
# ndata is number of points in each dataset
# cmag_*,  cmer_* are reference magnitude & dispersion for each aperture
# nskip_* is number of data points skipped when calculating cmag & cmer
# ra,dec,mag,mer are coordinates, magnitude and dispersion
# calculated directly from the data
#
# Each data row consists of the following fields:
# -  HJD-2450000
# -  magnitudes (one for each aperture)
# -  frame errors describing average photometric quality of the frame (for each aperture)
# -  frame number
# -  grade :
#    A - best data, no 29.999 (not measured) indication
#    B - mean data, no 29.999 (not measured) indication
#    C - A and B with 29.999 (not measured) indication
#    D - worst data, probably useless
#

#ndata= 9
#dataset= 1 ; 1 F0448-08_297
#desig= 050729-0524.5
#cra=    5.124594  05:07:28.5
#cdec=  -5.407535 -5:24:27.1
#class= 0
#cmag_0= 10.181
#cmer_0=  0.034
#nskip_0= 0
#cmag_1= 10.197
#cmer_1=  0.032
#nskip_1= 0
#cmag_2= 10.192
#cmer_2=  0.029
#nskip_2= 0
#cmag_3= 10.192
#cmer_3=  0.032
#nskip_3= 0
#cmag_4= 10.192
#cmer_4=  0.036
#nskip_4= 0
#ra=    5.124594  05:07:28.5
#dec=  -5.407535 -5:24:27.1
#     HJD      MAG_2  MAG_0  MAG_1  MAG_3  MAG_4    MER_2 MER_0 MER_1 MER_3 MER_4 GRADE FRAME
   2660.64728 10.114 10.094 10.112 10.120 10.114    0.018 0.052 0.031 0.017 0.016  A 35942
   3058.64152 10.179 10.143 10.205 10.173 10.171    0.020 0.080 0.028 0.021 0.022  B 91944
   3079.55730 10.197 10.194 10.212 10.196 10.192    0.016 0.058 0.024 0.017 0.018  A 94686
   3096.49376 10.193 10.215 10.191 10.197 10.201    0.013 0.041 0.020 0.014 0.015  A 96605
   3104.49154 10.198 10.185 10.174 10.197 10.209    0.013 0.050 0.023 0.014 0.014  A 97860
   3107.48959 10.205 10.199 10.221 10.202 10.206    0.014 0.050 0.026 0.015 0.015  A 98331
   3110.47844 10.169 10.160 10.161 10.169 10.170    0.012 0.044 0.021 0.012 0.012  A 98800
   3113.46895 10.161 10.150 10.170 10.159 10.149    0.014 0.045 0.021 0.015 0.015  A 99265
   3116.47063 10.253 10.258 10.257 10.263 10.271    0.013 0.048 0.023 0.013 0.014  A 99761
#ndata= 275
#dataset= 2 ; 1 F0520-08_298
#desig= 050729-0524.4
#cra=    5.124589  05:07:28.5
#cdec=  -5.407234 -5:24:26.0
#class= 0
#cmag_0= 10.214
```

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```
#cmer_0=  0.047
#nskip_0= 2
#cmag_1= 10.196
#cmer_1=  0.037
#nskip_1= 1
#cmag_2= 10.188
#cmer_2=  0.036
#nskip_2= 0
#cmag_3= 10.185
#cmer_3=  0.037
#nskip_3= 0
#cmag_4= 10.184
#cmer_4=  0.037
#nskip_4= 0
#ra=    5.124586  05:07:28.5
#dec=  -5.407173 -5:24:25.8
#     HJD      MAG_2  MAG_0  MAG_1  MAG_3  MAG_4    MER_2 MER_0 MER_1 MER_3 MER_4 GRADE FRAME
   1869.71038 10.224 10.280 10.233 10.226 10.227    0.017 0.036 0.020 0.019 0.021  A 273
   1870.71796 10.187 10.214 10.196 10.184 10.181    0.019 0.049 0.023 0.021 0.023  A 424
   1871.71726 10.188 10.197 10.195 10.187 10.189    0.019 0.048 0.023 0.021 0.023  A 554
   1872.71321 10.150 10.184 10.160 10.151 10.147    0.018 0.049 0.022 0.020 0.022  A 713
   1873.71521 10.139 10.139 10.147 10.142 10.146    0.015 0.043 0.020 0.017 0.020  A 876

   <...>

   3641.86587 10.230 10.221 10.242 10.230 10.235    0.016 0.044 0.023 0.015 0.016  A 160251
   3646.86873 29.999 29.999 29.999 29.999 29.999    0.021 0.061 0.034 0.019 0.019  C 160835
   3655.79894 29.999 29.999 29.999 29.999 29.999    0.021 0.043 0.023 0.021 0.023  C 162075
   3658.77001 29.999 29.999 29.999 29.999 29.999    0.020 0.054 0.027 0.019 0.021  C 162519
   3671.78278 29.999 29.999 29.999 29.999 29.999    0.018 0.048 0.026 0.016 0.017  C 164306
```

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16.4 Appendix 4 : example NSVS format

The *Peranso* Add Observation Set command allows to import observations from various predefined file formats. One of them is the **NSVS** (Northern Sky Variability Survey) **format.** This is the file format you get when copying observations from the NSVS website (select **Submit Query** -> **Object ID**) to your Microsoft Windows clipboard

Below is an example NSVS file to illustrate the file format. *Peranso* automatically extracts the observations from the file, retrieving their time (MJD) and magnitude. Fainter-than observations are skipped. All observations are bundled in one observation set.

MJD-50000	mag	err	flags
1401.386693	12.104	0.015	0
1401.387713	12.091	0.015	2
1409.314923	12.068	0.018	0
1409.315943	12.129	0.018	2
1426.245953	12.169	0.017	2
1426.246973	12.097	0.017	0
1426.402963	12.151	0.015	2
1426.403973	12.171	0.015	2
1427.244943	12.207	0.018	2
1427.245963	12.18	0.019	2
1437.304563	12.173	0.019	0
1439.439503	12.2	0.019	0
1439.440523	12.154	0.018	2
1450.195866	12.074	0.048	0
1452.216696	12.091	0.028	0
1454.215173	12.074	0.017	2
1454.216183	12.016	0.016	0
1454.368093	12.178	0.019	0
1454.369113	12.168	0.019	0
1455.248243	11.963	0.015	0
1455.249263	12.048	0.015	0
1455.403213	12.156	0.019	0
1455.404223	12.086	0.018	0
1456.204663	12.123	0.016	2

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